

et. finishing

APPLICATION, ELECTRODEPOSITION, VITREOUS ENAMELLING,
ANODIZING, METAL SPRAYING, METAL FINISHING PROCESSES

VOL. 1 No. 10 (new series)

OCTOBER, 1955

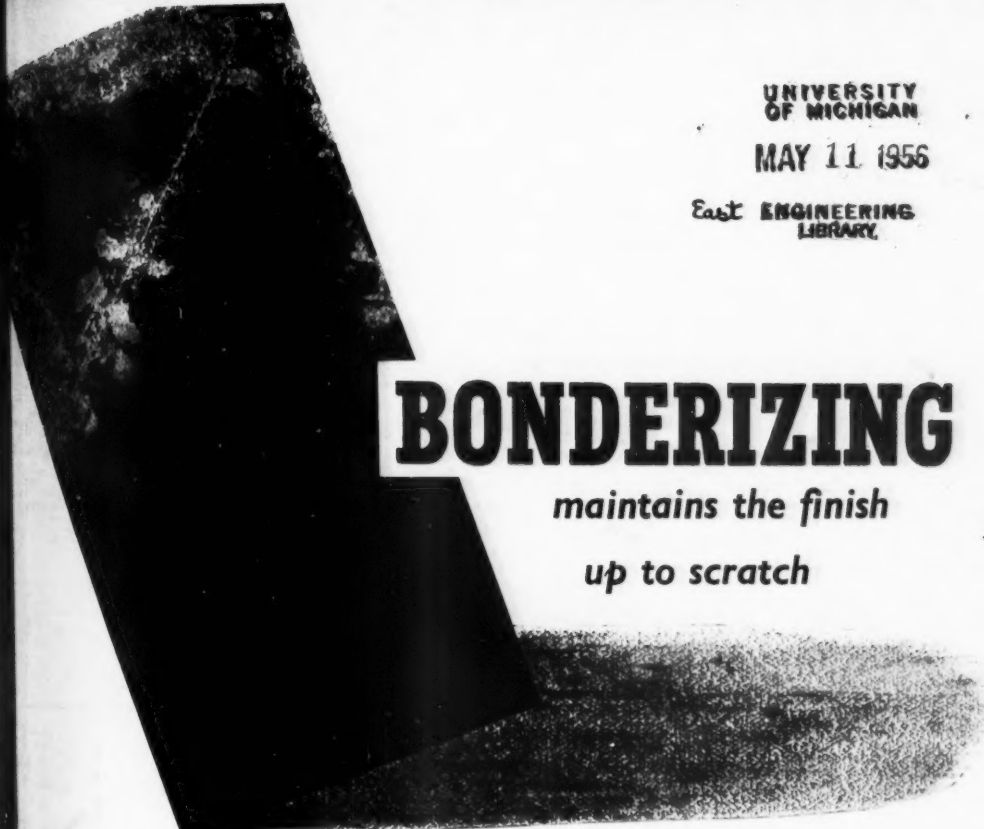
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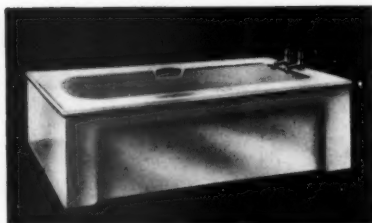
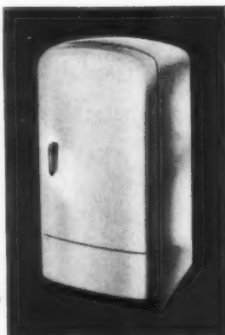
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metal finishing Journal

OCTOBER, 1955



Vol. 1 No. 10 (New Series)

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J. D. GARDOM
John Gardom & Co., Ripley, Derby
Telephone: Ripley 136

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JOHN ADAM HOUSE
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THIS JOURNAL IS DEVOTED TO THE SCIENCE AND TECHNOLOGY OF PAINT APPLICATION, ELECTRODEPOSITION, VITREOUS ENAMELLING, GALVANIZING, ANODIZING, METAL SPRAYING AND ALL METAL FINISHING PROCESSES.

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FULL CIRCLE

FASHIONS and crazes are of no less significance in the male industrial world than they are in the realm of feminine wear and they are pursued, supported, discussed and criticized with no less vigour. Similarly, some movements are cyclic, in that a particular vogue recurs at lengthy, indefinite intervals, and others are progressive whereby a style, once abandoned, is relegated to the limbo of forgotten things.

It can well be imagined for example, that a progressive industrialist at the time of what will probably come to be known to later historians as the first industrial revolution, emphatically declaiming to his fellows the virtues of his new Watt beam engine. 'Power' one can almost hear him say, 'That's the answer, more power, and put an end to this slow and costly manual labour'. And, as we know today, more power was the answer and much of the slow and costly hand work was replaced by faster mass-producing power-driven machinery, which made available services and consumer goods at prices within the reach of a much greater percentage of the population.

So the nation, and, shortly afterwards the rest of the world likewise, entered upon the golden age of mechanization. In subsequent years the use of machinery was taken for granted and although, necessarily, considerable improvements in efficiency of machines took place, there was no one who was called upon to argue in defence of their use or to advocate their wider adoption. But today the wheel has turned again full circle and once more the same cry goes up—manpower is scarce, costly and slow, we must replace it with machinery. Although today a new jargon has been coined and the talk is of productivity and automation, of robots and production aids, the need however, remains unchanged—to turn out more goods at lower prices and to extend markets still farther down into the underlying income strata.

As in most other industries, this fashionable trend has not been without its influence on the composite medley of crafts and sciences which make up the metal-finishing industry and today ways are increasingly being sought to apply the fundamental tenets of the mechanical age to the finishing shop.

It has often been said in recent years that finishing as a process, as a department, or even as an industry has not been accorded by management the recognition that it deserves and that it is often relegated to an under-equipped, ill-planned part of the works on which all development expenditure is begrudged. These strictures on British industrial management have not, in the main, been entirely undeserved in the past, but there is today evidence that the current vogue for greater use of automatic or semi-automatic mechanical processes is causing the light of investigations to be shed even into the inmost corners of the darkest plating shop.

In our visits to modern finishing installations in this country and overseas, some of which have been, or will be, described in our pages, it has always been abundantly apparent that the rewards for treating the finishing of a component as of equal importance to the manufacturing processes which produce it, are very real and substantial. This is a point which we will seek to establish beyond cavil in the months to come.

In the present struggle for economic survival, the potential savings that can be achieved, and the wider markets that can be entered by proper attention to the productivity aspects of finishing are of major importance.

In fact if it were to become fashionable, as it certainly should, to regard the finishing department, not as the Cinderella but as the Fairy Godmother of industry, it is not too much to claim that it would be one of the most important single contributions to our economic welfare possible at the present time.

Talking Points

by "PLATELAYER"

TOPICAL COMMENT
FROM THE MAIN
LINES AND SIDE
LINES OF METAL
FINISHING

ARTS FOR ARTS SAKE

DESPITE all that has been said regarding the need for increasing the supply of science graduates in this country, the present position is not encouraging. The number of technically qualified people leaving the universities and technical colleges has become almost stationary, although it is estimated by industry that demand exceeds the current supply by something like 30 per cent. Even here the estimated deficiency may be short of the real need.

Last year the total number of graduate scientists and engineers was 0.9 per cent of the population, as compared with over 2.0 per cent in U.S.A. The Soviet Union is now creditably reported to be producing more qualified scientists than the rest of the world put together.

Yet astonishingly enough, something like 40 per cent of the graduates from our universities qualify in the arts. Why this should be so is something of a mystery, considering the limited scope which the arts man has as compared with that open to the science or engineering graduate. Although there is a variety of reasons conducive to this situation, some of which are based on tradition and a prejudice against the methods and conditions of industry, undoubtedly a good deal of the responsibility goes further back than this. There can be little doubt that, generally speaking, the calibre of the average arts master in the grammar and public schools is superior to that of his science colleague, perhaps largely because of the more numerous alternative openings available to the top-grade science graduate. The effect of this is to incline students towards arts studies at an age before specialization has started; the influence of the personality of the teacher on a pupil at an impressionable age is no small factor in determining his future career.

SIC TRANSIT . . .

THE inevitable has happened perhaps sooner than was expected—the automatic laboratory is here. Developed for the Atomic Energy Research Establishment, the first unit is engaged in continuously analyzing uranium liquors, and replaces three skilled analysts working an 8-hour shift. The device draws a sample of the liquor periodically, reduces it with hydrogen, transfers it to an absorptiometer where it is examined and records the concentration automatically on a

chart in grams per litre. Fault alarms and safety devices prevent incorrect readings being obtained. All the metering and transfer operations are fully automatic, and the procedure can be adapted to a very wide range of analytical procedures.

While the automatic factory is still in the future, it comes as something of a shock to find that the (ostensibly) more skilled and individual processes of the laboratory should succumb to the onslaught of automation first. When one sees the simplicity of this equipment as compared with an automatic computer, it seems that the problem of automation as applied to skilled laboratory operations may prove easier to tackle than that of routine clerical work. One can imagine that ultimately the collection of litter after a Bank Holiday will be one of the few jobs to resist the advance of automation, and the man doing it will be the aristocrat of the labour market.

THROUGH THICK AND THIN

New methods for the non-destructive thickness testing of coatings are still coming into operation. The latest is one installed on an electrolytic tinning line in the U.S.A. which continuously records the tin thickness to an accuracy which is claimed to be of the order of .0000006 in. The method is based on making use of X-ray fluorescence. The X-rays are beamed on to the coated strip causing fluorescence of the steel. The radiation is absorbed by the tin coating as it leaves the steel surface, and by measuring the reduction in the emission of radiation (which is proportionate to the tin thickness) the weight of coating can be continuously recorded as the strip moves through the plant at 2,000 ft. per minute.

As I pointed out in these notes some months ago the problem of continuous non-destructive coating thickness determination has been solved by several methods, all of which, however, are too elaborate and costly for everyday use in the small- or medium-sized plant.

Thoughts for the Month

Polishing Costs. All is not gold that glitters - but it might just as well be.

Inspection. The man who looks on the bright side of things doesn't see the part they haven't plated.

A Comparative Survey of STOVING by CONVECTION and RADIATION

by LEO WALTER, A.M.I.Mech.E., M.Inst.F.

THE relative merits of convection heating as against radiant heating for stoving of metal finishes cannot be easily defined. The reaction of paint manufacturers to the question seems to be evasive. One of the largest makers of industrial paints when approached on the future developments to be expected observed that while they undoubtedly had a great deal of experience in formulating paint suitable for both radiant heat and convection stoving, the subject of stoving methods is one on which finality has not yet been reached and there is still plenty of scope for controversy.

Opinions of makers of ovens are similarly very guarded. Some of them manufacture only one type of stove, namely either convection ovens or radiant ovens. Naturally these firms will press the claims of their particular stoving method as often as circumstances permit. Other firms, making both oven types, seem to rely on empirical methods for coming to a decision in borderline cases as to which stoving method to recommend. They run tests in their well-equipped test laboratories and imitate during experiments, as far as possible such working conditions which can be safely expected in practice once their equipment comes in actual use. There are, however, many instances where a problem of stoving is clear cut, and where all factors of importance indicate the application of one method, and one only, for economy, reliability and output. In the following survey an attempt will be made to examine the relative merits of each stoving method, and to describe and illustrate a few typical practical examples. Based on the long experience of makers and users of convection stoves and of radiant ovens alike, economic and production factors can in these case histories be analysed for the benefit of the potential users of stoving equipment. Before dealing with these two main factors of cost

per stoved unit and of output and time for reaching it, a few basic considerations should be mentioned.

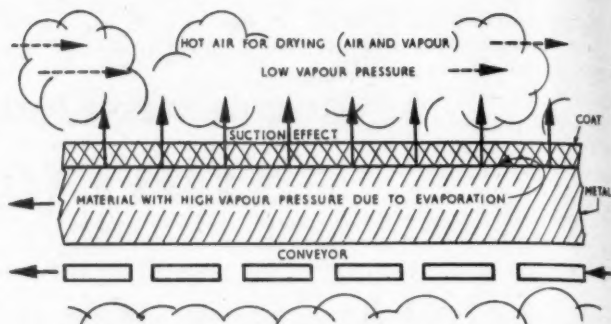
Methods of Heat Transfer

The two main heat transfer methods used for drying of coatings on metal surfaces are based (a) on application of warm air currents, and (b) on the use of invisible heat rays from a hot emitter source, called radiation.

Dealing first with convection stoving, the heat carrier is hot air, and the following heat transfer operations are applied: First, heat is transferred from a primary heating medium, which can be gas, steam or hot water, or electricity, to hot air. The second heat transfer occurs from this hot air to the coating material, where evaporation of moisture or of the volatile matter in the coating takes place. Forced convection stoves of modern designs produce a vigorous short-time heat transfer, assisted by fans. Quicker rates of stoving require, of course, higher air temperatures and larger air volumes and speeds. The higher the air temperature the more humidity and/or solvent vapours can the air absorb. A large pressure differential between the invisible water vapour always present in the air and the emanating solvent vapour from the coating will determine the "rate of stoving." In drying of paints or lacquers the hot air will produce a high water or solvent vapour pressure first near the surface of the coating, but gradually heat will penetrate and solvent will be evaporated from the inner layers. It is obvious that the physical and chemical qualities of the coating material have to suit not only the above thermal factors, but also other factors such as direction of flow of air (concurrent, counter-current, crossflow), the size and shape of the goods, and the desirable time of stoving.

For warm air drying the following factors have

Fig. 1.—Diagram showing that vapour pressure produces suction effect in hot-air drying of coated metal surface.



to be considered: (1) critical temperature of the coating material; (2) the time allowed for producing the required dryness; (3) humidity content of coating material; (4) output from the plant and stoving cost per unit weight of material.

Basic Aspects of Warm Air Drying

During the first stage, surface moisture, and during the later stages, moisture from inside the coating material is driven out. The driving power for moving "inner" moisture towards the surface is a pressure differential between the water vapour within the material and the partial vapour pressure in the air.

Fig. 1 illustrates how this pressure difference produces drying. The "boiling" inner moisture is driven out by means of the higher vapour pressure, which later overcomes the existing resistance. In instances where the paths of movement of evaporated moisture are blocked, and where inner moisture cannot escape, surface hardening occurs. The reason for such "case hardening" is usually to be found in overdrying during the first phase of drying, whereby the outer pores of the coating material contract and thus hinder movement of inner moisture towards the surface.

The basic operations for stoving efficiency—simple as they are—require some explanation, as users are not always fully conversant with the underlying principles. Efficiency of stoving can be considered in terms of the output and the cost per unit weight of material. Thermal efficiency can be defined as the relation between output and heat required for evaporation of moisture, *i.e.*, heat input. By bringing the energy introduced into a stove in the form of heat, power, etc., into comparison with the results achieved, several similar stoves can be analysed.

Where a forced convection stove is operated at excessive fan speed, power is obviously wasted to no useful purpose. Where, on the other hand, the humid air is not carried away quickly enough, through the exhaust fan being inadequate, time is obviously wasted. Should it be necessary to

operate at lower speed than designed—due to lack of efficient steam trapping and air venting of the steam-heated coils—the thermal efficiency and output will be unnecessarily low. The most efficient stove will only work far below its rated efficiency if working conditions are unfavourable. Change of the manufacturing methods, installation of an intermittent heavy steam consumer in an adjacent works department fed from the same steam supply mains as the stove, may cause periodical steam starvation with consequent erratic output. What should be realized is that a stove possesses not only internal characteristics inherent to the design, but also external characteristics, depending on working conditions, and that these may well exert the greater influence.

Another point to be considered for efficiency of stoving is loading. Partial loading of any type of oven whether batch or continuous, brings down thermal efficiency, as do frequent stoppages of conveyor stoves. Although it is obvious that a stove has been designed for full load, irregular loading is often encountered in practice, with the result that overloaded stoves require longer time for the same output with resulting larger heat losses, whereas underloaded ovens waste heat by using more hot air or steam than necessary.

Operation of hot-air stoving

The practical operation should closely follow the intentions of the designer of the plant, provided the apparatus is being used for the purpose and under conditions for which it has been ordered. This is, however, not always the case, *e.g.*, where a stoving apparatus has been "home-made" or bought second-hand.

It also sometimes happens that a stove has been installed for a certain product, but production has changed over to another product, followed by a switching over to new working conditions, without much investigation as to whether the oven is really suitable for the new duty.

Although it is obvious that hot-air stoving requires that fresh warmed air particles are con-

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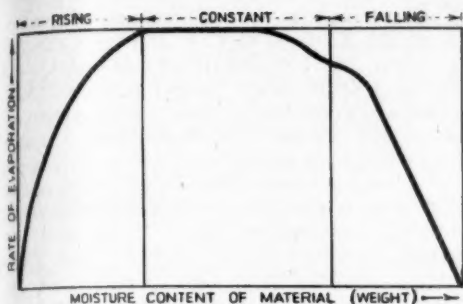


Fig. 2.—Stages of hot-air drying.

continuously brought into contact with the goods, this point is sometimes neglected in stoves, where air circulation is imperfect, forming "dead corners" with more or less stale air. It is not surprising that uneven results are produced. This should not be tolerated, and where bad distribution of hot air is obviously the cause of bad output, the only remedy is to improve this by means of baffling, or by installing an additional fan or heating surface. Uneven temperature distribution may also cause discoloration of part of the goods or a lowering of quality coating, which in the end may reduce the quality of the whole batch with consequent losses in sales price. Where it is desired to work at top efficiency, ways and means can nearly always be found to improve operation of an imperfect hot-air stove.

Thermal and Overall Efficiency (Fig. 2)

Standby losses of continuous ovens, using conveyor belts or other means for moving the material through the apparatus, can be considerable. Convection stoves consume heat and steam, unless heat input is shut off by the plant operator if stoppages occur. To leave steam on full bore during these breaks means waste of fuel and money. During the lunch hour, the proper closing of steam valves to all idle consumers of steam should be ensured. The issue of precise instructions to operators will assist in the reduction of heat losses from this source.

Heat losses during heating-up when starting a machine from cold are inevitable, but they can be reduced by shortening heating-up time. All such heating-up and standby heat losses should be carefully investigated; the provision of a time schedule, to which foremen and operators have to adhere, will be found of value.

Where a hot-air stove works under higher air pressure, hot air lost through leakages has to be replaced by warm air, thus causing wastage of heat and power for driving fans. Air infiltration in the feed end and at the discharge end of

conveyor dryers can be prevented by keeping openings as small as possible and by providing trap doors. Air leakages from an oven under pressure can be easily detected by means of a lighted candle, and any cracks or slits in steel plate work or duct work should be sealed.

The following considerations apply not only to hot-air drying and stoving, but also to drying by means of hot gases, whereby the products of combustion are diluted with air; this hot mixture is brought in direct contact with the material.

In general the factors which influence oven performance are: temperature, humidity, speed of air movement, and, for continuous stoving, rate of movement of material.

In any type of stove, whether batch or continuous, the quality of stoving depends on balancing heat input and rate of evaporation at any particular moment. The means of influencing rate of stoving, whether by hand or automatic control, are:

- (1) Change of temperature.
- (2) Change of humidity of air.
- (3) Change of velocity and/or direction of air, relative to the material.
- (4) Change of air volume.
- (5) Change of conveyor speed or of speed of material through a continuous oven.
- (6) Change of moisture content of coating.
- (7) Physical and chemical qualities of the coat.
- (8) General working conditions.

Each of the above factors can be controlled, thus achieving a correct rate of stoving.

Methods of Radiant Stoving

Since the time when the first emitter panels for radiation stoving were designed, many years ago, great progress has been made in construction of radiant-heating methods. Operators of radiant ovens, whether of older or of very recent design, should be familiar with the results of application of invisible heat rays which generate the required heat on the coated metal surface.

Thermal radiation is emitted from hot bodies in the form of invisible heat rays. The intensity of emission and its distribution depends upon the nature of the emitting body, its temperature, and its shape. When heat rays are sent out from a radiant panel they penetrate the air without heating it up, but when they fall upon a solid material, some of the thermal radiation is absorbed and heats up the solid body. Some of the invisible radiant heat is reflected and if these reflected radiant rays fall upon a body the same happens again. In general, dark and rough surface bodies absorb radiant heat rays more readily than light-coloured and polished surfaces.

Radiant heating panels as applied for infra-red

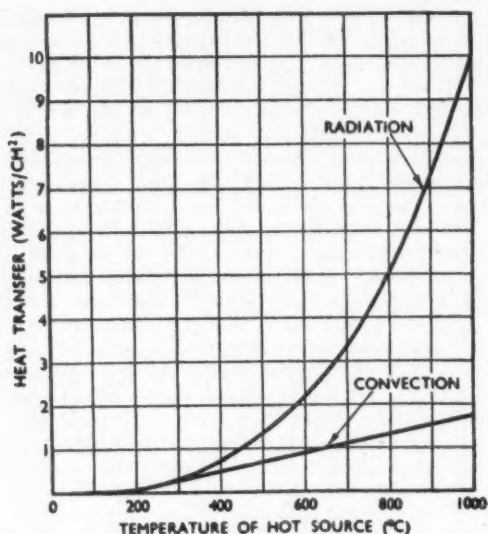


Fig. 3.—Graph showing comparison of heat transfer by radiation and convection.

drying use medium temperature radiation, and can be heated by electricity or by gas. It should be noted, however, that infra-red drying may at times also use convection as part of the heat transfer. Drying and baking of coatings and finishes use mainly heat transferred directly from the source to the object to be heated in the form of thermal radiation, but convection heat is also more or less present and raises the air temperature within the drier or stove, particularly where large metal panels are employed.

The advantages of infra-red or radiant heating may be summarized as follows: Heat transfer by means of heat rays is instantaneous. It is not necessary for the object to be heated to come up to temperature inside the drier, i.e., to be heated up to oven temperature as happens in hot air driers. The heat transfer is independent of the temperature of the oven atmosphere and takes place rapidly. The rate of heat input is very high, but this rate can be easily varied by switching radiant panels on or off and also by varying their surface temperature. A large proportion of the radiant heat input is employed on useful work, and is not lost in warm exhaust gases or warm air leaving the oven, as is the case with hot-air baking.

Source of Heat (Fig. 3)

It should be noted that heat rays responsible for the transfer of energy are essentially the same whether generated by an electrically or gas-heated source. These rays are of longer wave length than visible radiation (light) and lie in the so-called

"infra-red region" of the spectrum. There is a difference between electric and gas radiation however, because the temperature at which electric radiant panels using tungsten filaments operate is much higher than the temperature of gas-heated sources, and consequently the rays emitted from the lamps are of shorter wave length than those from normal gas-heated radiant panels. As shorter radiant waves are more easily transmitted this appears to be an advantage for electric panels, especially in the case of paint films, because skin-drying is thus avoided. On the other hand, makers of gas-heated driers claim that when using a medium-temperature gas-heated tunnel made from blackened sheet steel for paint drying, which may be operated up to 700° F., good results are obtained in the treatment with gas heat. Among the advantages of gas radiant heating are claimed the following:—

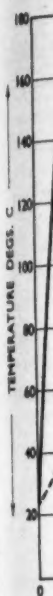
- (a) No reflectors to keep clean.
- (b) Very even distribution of radiation.
- (c) Range of flux density can be very much greater (if desired 10 times) for gas flux than the electric flux.
- (d) Emission of spectrum is such that the effect of paint colour is generally less marked than for electrical systems.
- (e) No elaborate electrical equipment is needed for radiant gas drying.

On the other hand, makers of electrical infra-red drying equipment rightly claim that infra-red lamps have been successfully applied to the baking and drying of paint on all manner of articles, and are very economical in operation. For example, cost of electric radiant heat can be lower than with gas, and about one-half that for conventional ovens using convection for batch stoving.

Stoving Schedules

For paint stoving the usual procedure is that the paint manufacturer prepares a stoving schedule which, however, may have to be somewhat modified according to working conditions. Since the majority of stoving paints have to be cured or hardened by the polymerization of their resin content the correct curing of paint films depends mainly on (a) time, and (b) temperature. Correct stoving requires, therefore, the right time coupled with the correct temperature, and it is here where a little experiment can sometimes improve stoving efficiency in practice.

Bearing in mind that, generally speaking, a long period at low stoving temperature can be equivalent to a shorter period with higher temperature, an examination of alternatives in practice might sometimes produce economies in operation. Questions of shading of larger articles or possibility of submitting certain sections of an article



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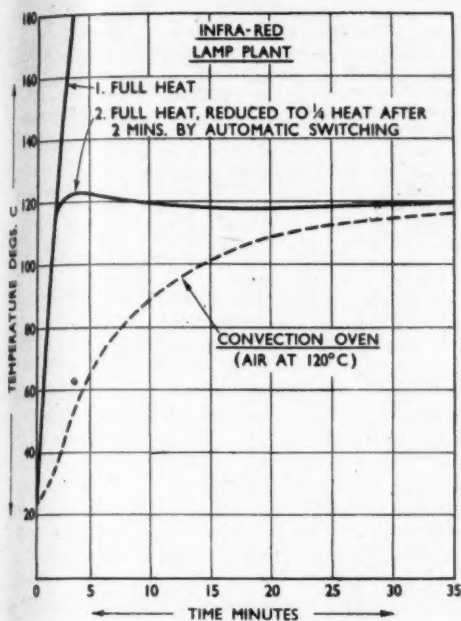


Fig. 4.—Times of stoving a steel panel.

[Courtesy of the General Electric Co., Ltd.]

to longer stoving than other parts, or the use of different temperatures and intensities of radiation during movement of goods will turn up in practice and must not be neglected or brushed aside. Investigations by a specialist will often produce evidence that the oven could be operated more efficiently (Fig. 4).

Summing up, the main factors to be considered in radiant heat treatment in conveyor or tunnel stoving ovens using electric radiant elements are as follows:

(1) Rate of Heating Up. This will depend for various goods on the ratio of surface area to weight. The greater the surface area exposed directly to the radiating oven, the more heat the work will receive in unit time. Similarly, the lower the weight the less will be the heat required for a given temperature rise, but the shape of the article also has to be considered.

(2) Limiting factors in the speed of drying will be as follows:

(a) Type of paint used. Most of the large paint manufacturers today make a special line of paints for radiant drying and all are very willing to give advice. It may be that the paint in use in hot-air drying will be quite satisfactory, and when switching over to radiant heat, no change will be necessary.

(b) Particular characteristics of the article to be heated. The nature of the product or of a

component part may not withstand the rapid rise in temperature produced by radiant heat, for instance spring steel, fabric, backed metal, etc. In such cases the work and not the paint is the limiting factor in drying conditions. Radiant heat may still be used, but a compromise between temperature and time will have to be considered.

(c) Speed of production in the factory. There is no point in reducing the speed of drying to, say, one minute for each article if the flow of articles from the factory to the oven cannot keep up with this speed. The result would result in a bottleneck with intermittent use of the oven. It would be better in such circumstances to reduce the speed of drying. This can be achieved by slowing down the conveyor and either lowering the oven temperature within limits, or shutting off one or more end sections so that the oven runs full and continuously.

It is a question of economy to use electric current sparingly. When contemplating installation of a new baking oven or tunnel using infra-red heat rays, it is highly advisable to investigate carefully the running cost with various alternative heating media. Prices of heating media vary according to local circumstances.

Stoving methods using radiation depend for heat transfer not only on the source for infra-red rays, but also upon the material being stoved. The fundamental fact about infra-red radiation is that the heat rays penetrate an air space without heating it. Heat is only generated once the infra-red rays meet a solid body. If certain parts of a stoved article are shielded from these rays, they cannot be directly heated, but they receive some heat from nearby heated sections of the article by conduction of heat *via* the metal. They also receive some heat from convection air currents which are produced from heated surfaces nearby. Nevertheless, shielded sections of an article have to work under very slow heat-transfer conditions. The main factors for rate of enamelling or of paint or lacquer coating by means of radiation (whether the emitters are gas-fired or heated by electric current) are, therefore: (a) Flow of heat, depending on temperature and area of emission, (b) time of radiation, and (c) colour and other surface qualities, of the stoved articles. Other factors are the distance between emitter surface and article, colour and quality of coating, thickness of the latter, and last but not least the time allowable for economical stoving.

In the following observations it is always assumed that the correct type of enamel has been chosen in co-operation with the manufacturers of same, so that thermal factors only have to be

TABLE I.

Gas Stoving by Emitter Panels of painted Metal Articles. (Courtesy of Parkinson and Cowan Ltd.).

Article	Material	Panel Temp.	Paint Colour	Baking Time	Remarks
Child's paint box ...	MS 22 swg.	650°F.	Black & White	2 mins.	Both colours dried at same time
Cycle chain guards ...	MS 24 swg.	650°F.	Black	1½ mins.	
Clips for chain guards	MS 14 swg.	650°F.	Black	2½ mins.	Paint not entirely suitable do.
Cycle fork ...	MS varying section	540°F.	Blue	12 mins.	
Cycle frame ...	MS varying section	540°F.	Blue	7½ mins.	
Folding tubular chain frame ...	MS 15 swg.	650°F.	Cream	3 mins.	Thickness of wire made longer time necessary
			Pale Blue	3 mins.	
			Pale Green	3 mins.	Time increased by heavier bracket
			Green	4 mins.	
Vegetable rack ...	MS 18 swg.	650°F.	Green	3 mins.	
Small kitchen tidy ...	MS 18 swg.	650°F.	Green	3 mins.	
Clothes line reel ...	MS 24 swg. with 16 swg. bracket	650°F.	Green	3 mins.	
Sections of neat safe	MS 20 swg.	650°F.	Green	1½ mins.	
Small tins for Kitchen Cabinet ...	MS 20 swg.	650°F.	Green	2 mins.	
Bread Bin & lid ...	MS 18 swg.	650°F.	Green	3½ mins.	
Iron Casting 2 lbs. ...	Cast iron	650°F.	Dark Green	10 mins.	
Iron Casting 4 lbs. ...	Cast iron	650°F.	Dark Green	12½ mins.	
Iron Casting 6 lbs. ...	Cast iron	650°F.	Dark Green	12½ mins.	
Iron Casting 15 lbs. ...	Cast iron	650°F.	Dark Green	25 mins.	
Oil Drum ...	MS 16 swg.	650°F.	Dark Green	4 mins.	About 18 in. dia. by 30 in. long. Ends dry
			Cream		
Coal Hod. ...	20 swg.	650°F.	Black	2 mins.	

considered. Fusing of a glass composition to a metallic surface require definite constituents, and correct dipping, spraying, or brushing methods of the slip. Assuming complete evaporation of the water that is the carrier for the powdered enamel, fusion will then take place in furnace temperatures between 750° and 925° C. Similarly, where lacquers or varnishes on metallic surfaces are being dealt with it is assumed that thickness of a coating is such that vapour evaporation from the coating is as rapid as possible due to chemical composition of the coating.

Influence of Operation of Convection Stoves on Results (Fig. 5)

A good stoved finish on a metal surface requires the best possible heat transfer. Efficiency of any industrial oven type depends very much

on the effective use of three means of heat transfer, namely, conduction, convection and radiation, in relation to the job being done. It should be understood that radiation can be present in a convection stove, but similarly convection heat is present in a radiant stove, and transfer of heat via the metal to be coated always takes place, irrespective of method of heating in a stove.

In discussing operation of oven-types, four descriptive words are generally used. They are "direct," "indirect," "external" and "internal." In a direct oven system the products of combustion are permitted to come into direct contact with the work. The combustion equipment may be inside or outside the oven. Factors of importance are efficient combustion, good adjustment of fuel/air ratio on burners, correct dilution of combustion gases with air, and desirable draught conditions.

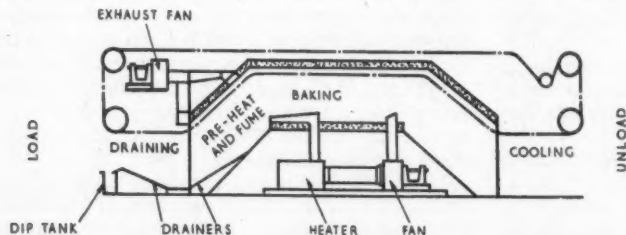


Fig. 5.—Layout for convection conveyor oven.
(Courtesy of A. E. Griffiths (Smethwick) Ltd.)

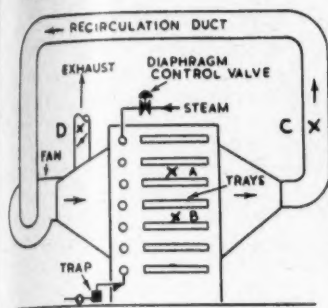


Fig. 6.—Controlled recirculation in tray-type dryer. NOTE: points A-D are places of temperature measurement during investigation.

In an indirect system where either a heat exchanger is used between combustion gases and hot air, or where the heating medium is steam, hot water, town gas or electricity applied to an air heater, the main point to be watched is a clean heating surface, and good heat transfer. For example in a steam-heated air-heater battery, frequent cleaning of the outer surfaces of the tubes is advisable, and correct steam trapping and air venting will help to avoid waterlogging with consequent temperature drop.

Recirculation of air in modern forced-convection stoves (Fig. 6) results in better thermal efficiency, and increases heat transfer rate. Forced recirculation of this type can vary between 4 to 50 air changes per minute. The direction of hot-air flow must match the shape and position of the goods. Thus a horizontal movement would not be satisfactory for heating up metal sheets hung vertically, and a vertical air movement would not be useful for baking articles placed on horizontal trays. In modern convection ovens forced circulation and recirculation of air greatly speeds up heating action. As mentioned before many an older type of convection oven lends itself to modernization by introducing a fan and air baffles, and/or recirculation.

In his paper (see bibliography) Mr. A. H. Lehmann states that convection drying is particularly advantageous for treating tin-plate sheets. These sheets can be stacked vertically in wire frames at approx. 1-in. pitch on a travelling conveyor. With a radiant heat oven the sheets pass flat on a conveyor through the emitter zones, thus taking up much more space (about 4,000 sq. ft. for radiant heating as against 555 sq. ft. floor space occupied).

Common Misconceptions in Stoving

One of the commonest misunderstandings of operators of infra-red ovens is that results are entirely dependent upon radiation, to get heat to an object to be stoved. For convection stoving it is also thought that convection ovens depend

entirely upon contact between hot air and metal surface of the goods. In practice it is impossible to separate these two heating methods, and in addition heat flow by conduction, *i.e.* through the metal itself is always present. Efficiently operated infra-red ovens make wide use of the hot air in the heating zone. If they did not, some of the shaded parts of articles would obtain very little heat, and fuel cost would be high. Convection ovens, even of the indirect external type, make use of radiation in their operation. What happens is that the hot rapidly moving air coming from a heater radiates heat through the slower moving air "skin" (stagnant air film) in contact with the surface of the articles during stoving.

Another false idea can be that gas heats faster than electricity, or *vice versa*, or that a steam coil heats more rapidly than a hot water coil in a heater battery. In any type of oven it is the temperature, heating surface, and the design which determines speed of operation, irrespective of nature of the source of heat.

Estimating Power and Heat

Power required by a convection stove is mainly used for driving fans, but for continuous conveyor ovens power requirements for moving the articles may be considerable. The ventilation requirements depend on design, working conditions, and safety figures for avoidance of explosion hazards. For example a basic figure for ventilating air for batch ovens may be 420 cu. ft. of air per minute per gallon of solvent vaporized, at 70° F. In conveyor type ovens about 12,000 cu. ft. of air may be blown in for each gallon of solvent evaporated. Thus if solvent is evaporated at the rate of one gallon per hour, the ventilation rate would be 12,000 cu. ft. per hour, or 200 cu. ft. at 70° F. From oven manufacturers' tables the power required for a ventilation fan can thus be obtained.

Basic figures for calculating air and heat requirements for a convection oven are as follows; 1 cu. ft. of air weighs 0.075 lb. For raising 1 lb. of air one degree F., 0.24 BTU's are required. Steel has a specific heat of 0.110 or in other words 0.110 BTU's are required to raise steel temperature by 1° F.

A sample calculation can now be done. Consider a conveyor-type oven in which it is desired to bake 1,000 lb. of sheet steel parts at 350° F. for half an hour, after being coated with a finish containing 1 gal. of solvents. Aside from a small loss due to radiation from the oven walls, the heat requirement for this oven would be as follows; if the parts are heated from 70° F. at the start:

Metal heat absorption=

$$1,000 \times \frac{(350-70)}{0.5} \times 0.110 = 61,600 \text{ BTU}$$

Air heat absorption.

$$\frac{12,000}{0.5} \times 0.075 \times (350-70) \times 0.24$$

$$= 96,960 \text{ BTU}$$

Total heat required per hour equals 158,560 BTU.

Relating this to a fuel chart, if the oven was a direct internal oven, using gas at 1,000 BTU per cu. ft., the fuel requirements would be 158.56 cu. ft. per hour.

It should be noted that the air output, being hotter, will be much larger in volume than the air input. For 350° F., the factor is 1.53, so that an exhaust fan would have to be used that would draw $24,000 \times 1.53$ cu. ft. per hour.

Ovens are available using any of the types of fuel. Steam, generated from coal is a clean, simple, inexpensive, and reliable source of heat. However, it must be available in ample quantities at pressures above those needed to give maximum temperatures required in the baking operation to be useful. It is not usually economically sound to install a steam boiler just for use in an oven. Town gas and in some instances fuel oil is a cheap source of heat. However, because their products of combustion sometimes contain sulphurous or odorous gases, these fuels are not satisfactory for any direct heating application. Oil burners need more maintenance than gas, electric, or steam units.

Electricity may sometimes be a more expensive heat source, but the large variety of well-engineered heating units available using this kind of energy has largely circumvented this difficulty. Manufacturers of electrical heating units provide good engineering advice to industrial oven users. They have a large number of variable types of heating panels available which can be set up into fairly elaborate stoving ovens over a weekend.

The manufacturers of electrical equipment were the first to design and make available the bulb-type infra-red panel which is so widely used today. This panel provides easily controllable heat. It is simple. It is efficient. Generally speaking, the two main limiting factors of this kind of heating are cost of electricity, and the breakage of bulbs. In continuous operations this breakage happens at unpredictable times, and in order to get completely uniform heating, the panels must be located so that this breakage can be seen and bulbs replaced. In modern conveyORIZED systems, the trend is toward locating the oven on the ceiling. Bulb breakage brings about a difficult maintenance problem for such installations.

Effect of Coating Material on Cost

A number of surface-coating materials have been specially formulated for stove or oven drying. They will not dry or "set" unless subjected to higher temperatures. Many air-drying finishes may be dried by forced convection thus affecting economy in drying time, although oven temperatures are lower than with normal stoving finishes. Factors for stoving temperatures are, amongst others, formulation of the finish, base material, production rate (stoving time), shape and weight of article, air volume and speed, and many more. Working stoving temperatures vary between 300° and 400° F., but low-bake finishes require only 200° to 250° for drying. The time limit to which steel and other ferrous articles can remain in an oven depends at the critical temperature at which the coating begins to break down.

Practical experiences of one of the largest manufacturers of ovens for enamelling and lacquer drying have shown that one can beat the clock if stoving is performed at a temperature which would destroy the finish unless the articles were quickly removed after a special period of time.

According to this same manufacturer experience during the war years showed that the question of rapidity in drying, in most cases, relates in no way to the oven design, but to the new paints which are now available. The latter will dry by any known means of heating in considerably shorter times than before the war. For example, the linseed-oil-base paints for enamelling used in the cycle industry still take 45 minutes no matter which drying method is used. Modified linseed oils can be dried in 20 minutes, but the medium alkyd resin types of paint will polymerize in a very much shorter time. It is noteworthy when comparing time factors that the fundamental difference between oxidation of oils and polymerization of resins are all important factors when considering stoving schedules.

From the above it is understandable that reputable makers of stoves are somewhat reluctant to recommend straight away a definite method of stoving, without running tests. All that they are prepared to say and to prove is that "providing equal paints are used convection will dry just as quickly as radiation." The ultimate choice of a drying and stoving method becomes purely a matter of economics of fuel, floor space, and capital expenditure.

It is well known that with certain types of coatings, a minimum air-drying period is required, before stoving commences. This is obligatory as a fire precaution, and is required to promote evaporation of the more volatile constituents.

(continued in page 451)

A Description of

A New High-Productivity BARREL-PLATING LINE

at the Aylesbury Works of

THE BIFURCATED & TUBULAR RIVET CO. LTD.

MODERN industry makes use of rivets in vast numbers and of a very great variety of types. An important contribution to the supply of these ubiquitous components is made by the Bifurcated and Tubular Rivet Co. Ltd., at whose works at Aylesbury over 50 tons of rivets are manufactured each week. Not only are these rivets highly diverse in form and material, but they also need to be finished in a wide range of coatings. Some appreciation of this diversity can be gained from Fig. 1 which shows a very small selection from the more than three hundred thousand types of rivet currently held in stock by the company.

The finishes applied to these rivets include chromium, nickel, zinc, cadmium, copper, brass, tin (both electrolytic and hot-dip), silver, stove enamel, phosphate, anodized and dyed light alloy, and blued steel. The materials from which the rivets are made, apart from steel which accounts for some 85 per cent of the production, are copper, brass, aluminium and light alloy to B.S.S. L57 (D.T.D. 327) and 3L37.

Until comparatively recently the production of this great miscellany of plated coatings was carried out in open inclined barrels and horizontal semi-immersed barrels in which the plating speeds were

slow and which presented numerous difficulties in the handling of the multiplicity of types of rivet. A view of this early equipment is shown in Fig. 2.

The whole plating shop has been recently redesigned and equipped with horizontal totally immersed barrels by the Electro-Chemical Engineering Co. Ltd. of Weybridge, with very significant improvements in the general productivity and utilization of space in the shop. The savings in time, manpower and floorspace make a striking illustration of what can be achieved by proper planning of a plating installation as a production process.

General Description of Plant

A diagrammatic representation of the layout of the plant is shown in Fig. 3 from which it will be seen that following the preliminary degreasing and cleaning bay there are two process lines, one being a bright nickel line and the other a cyanide line. The general progress of work through the line is that, after manufacture, it is barrel burnished with dry sawdust, which removes burrs and gives a modicum of shine, after which it is degreased in a two-stage solvent degreaser. The degreased work is transferred to a Monel cylinder and then sub-



Fig. 1.—A small selection of the very large number of products finished in the new line indicating the wide divergence in size and shape.

Fig. 2.—A view of the original barrel plating installation which has been replaced by the new line. The old style semi-immersed horizontal barrels and inclined open ended barrels with their associated overhead belt drives are in marked contrast to the clean lines of the new installation.



jected to a hot alkali soak. After a rinse, an acid pickle, and a further rinse, the work is then transferred to a stainless steel loading chute for transfer to the plating barrels. The loaded plating barrels are carried on the monorail conveyor down the appropriate plating line where after plating the work is rinsed and discharged into perforated baskets. After a further rinse the work is drained and in most cases tipped direct into heated centrifugal driers.

Fig. 3.—Diagrammatic representation of the layout of the cleaning bay and the two newly installed barrel plating lines.

Key:

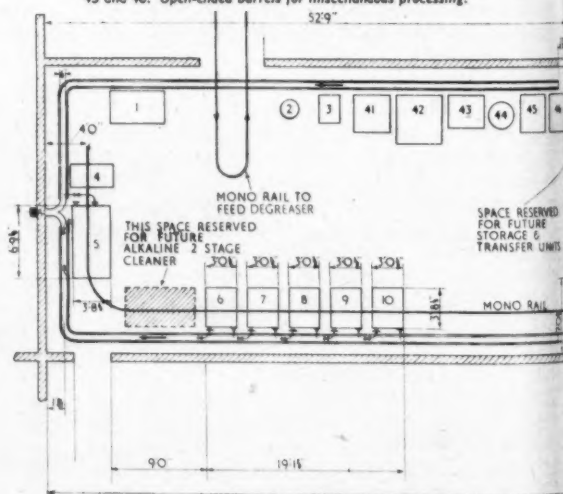
1. Two-stage solvent degreaser.
2. Solvent distillation unit.
3. Solvent storage unit.
4. Three-partition loading stage for cleaning line.
5. Two-stage alkaline cleaning tank.
6. Cold rinse.
7. Acid pickle.
8. Cold rinse.
9. Acid pickle.
10. Cold rinse.
- 11 and 12. Storage and transfer unit for plating line.
13. Tin plating tank.
14. Cold rinse.
15. Cadmium plating tank.
16. Cold rinse.
17. Two-stage copper plating tank.
18. Cold rinse.
19. Brass plating tank.
20. Cold rinse.
21. Zinc plating tank.
22. Cold rinse.
23. Unloading hopper.
24. Nickel solution storage tank.
25. Five-stage nickel plating tank.
26. Cold rinse.
27. Five-stage nickel plating tank.
28. Cold rinse followed by cyanide dip.
29. Cold rinse.
30. Hopper rinse unit.
31. Loading stand for dewatering.
32. De-watering oil tank.
33. Unload unit.

DETAILED DESCRIPTION OF PLANT

Cleaning Plant

The degreasing unit is a separate installation supplied by Technochimie of Zurich. This is a two-stage boiling-solvent degreaser, electrically operated and steam heated, with its own associated distillation plant. The machine consists essentially of a degreasing tank, divided into two compartments, each of which is fitted with a clean-

- 34 to 39. Projected layout for silver plating line, to be installed, comprising strike, cold rinse, silver plate, drag-out, silver plate and cold rinse.
40. Heated centrifugal driers.
41. Wet burnishing unit.
42. Phosphating unit.
43. Dye tank.
44. Centrifugal drier.
- 45 and 46. Open-ended barrels for miscellaneous processing.



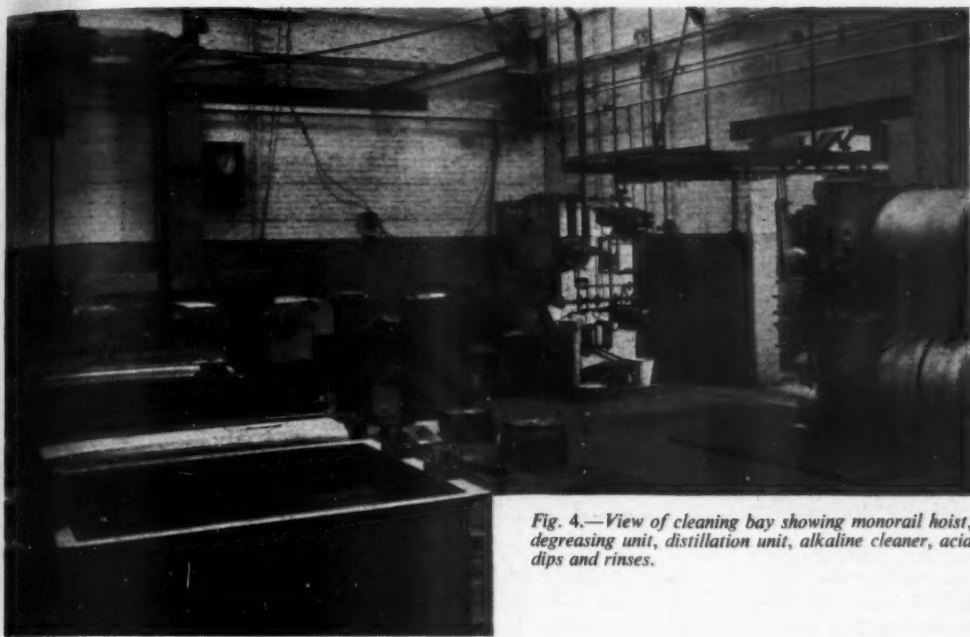


Fig. 4.—View of cleaning bay showing monorail hoist, degreasing unit, distillation unit, alkaline cleaner, acid dips and rinses.

ing manhole for the removal of solid residue, and with the necessary connexions for changing solvents. Heating is carried out with low pressure steam, the normal operating temperature being 85° C. Vapour given off by the solvent is condensed by a cooling system above tank level and returned to the last bath. A thermostat is fitted to cut off the heating system in the event of a failure

of the supply of cooling water. Water and soluble oil are separated from the solvent by means of a special filter, provided with the machine.

The upper part of the machine contains all mechanical parts, the loading and unloading station being to one side at a convenient height. Two endless conveyor chains, linked by traverse arms, carry the work basket holders. Work

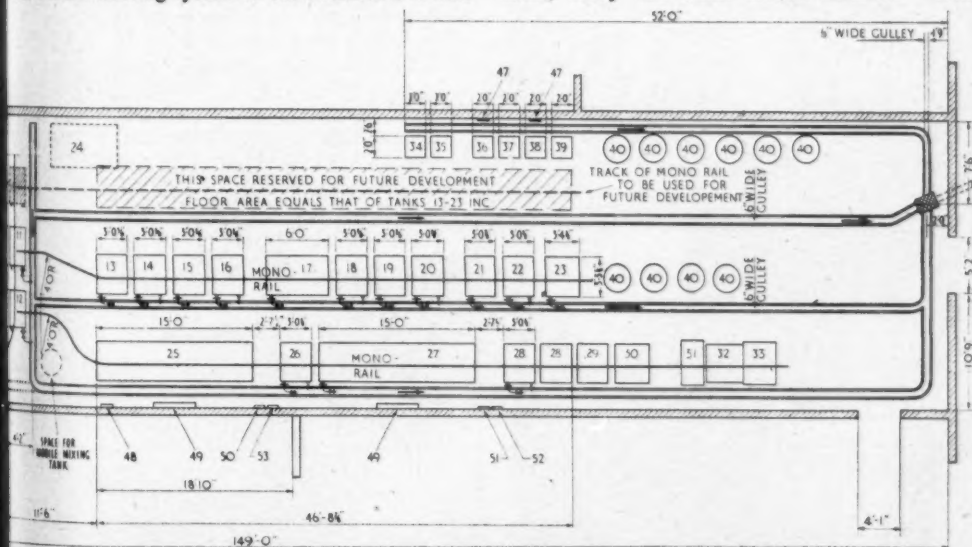
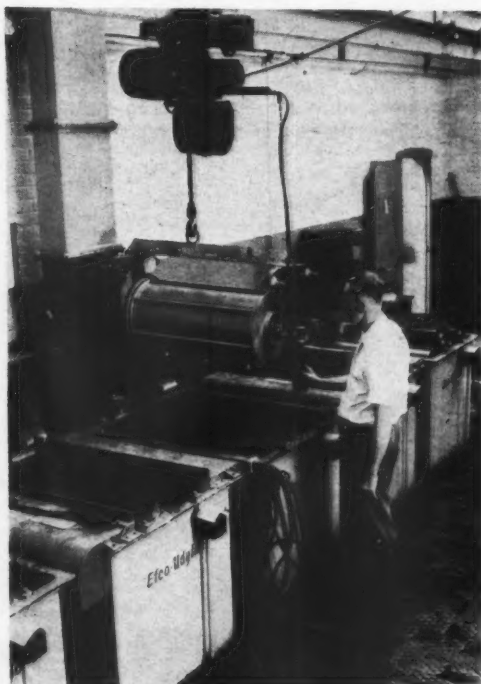




Fig. 5.—A work load being inserted in the solvent degreasing unit.

baskets, containing the articles to be degreased, are inserted into the work basket holders. The work baskets which are securely retained in position are of cylindrical shape of perforated galvan-

Fig. 6.—Work being processed through the cleaning line.



ized steel. The conveyor chains are driven by an electric motor, through a reduction gear.

The sequence of operations is synchronized. As soon as a basket holder arrives at the loading and unloading point, the conveyor chains are stopped. The operator removes the basket containing degreased and dried materials and inserts a basket of unprocessed work (see Fig. 5). During loading and unloading the other baskets remain immersed in the degreasing tanks or in the drying zone.

The baskets are rotated while they are being passed through the machine when the conveyor chains are stationary, a separate drive motor being provided for their rotation. This has the advantage that work is more thoroughly washed, resulting in more effective cleaning and drying, particularly when recessed parts are processed. Rotation of the baskets in the tanks or drying compartment can be stopped by the operator by push-button control.

After the operator has loaded a basket of work, he presses a push-button which sets the conveyor chains in motion again until the next basket is ready for unloading. The machine is provided with internal electric lights and an inspection window, through which the operator can observe the passage of the baskets through the machine. When the loading door is opened, a curtain of air is automatically drawn across the aperture, this, and the arrangement of the cooling coils, resulting in the complete absence of smell through leakage of fumes. The degreased work is entirely dry and odourless when removed from the machine.

Contaminated solvent is continuously pumped from the first solvent chamber and passed to the

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Fig. 7
hopper

distillation unit, where it is distilled, and the purified solvent recirculated to the clean side of the degreasing unit. In this still, overheating and consequent decomposition of the solvent is avoided by the use of indirect heating. By using indirect heating the surface temperature is not permitted to reach more than a pre-determined maximum, well below the temperature of decomposition. As soon as the temperature is insufficient to evaporate the mixture to be distilled, steam is blown directly into the still, this causing the boiling point to be reduced and resulting in a mixture of steam and solvent vapour reaching the condenser, in which a suitable device separates the two liquids thus obtained. This method enables 100 per cent distillation to be obtained without any risk of overheating. Moreover, residues in the still contain no trace of solvent and can be emptied without any vapour or smell.

The operation of this unit has been very satisfactory and has resulted in savings of up to 75 per cent in the consumption of trichlorethylene compared with the earlier installation.

The capacity of the plant is approximately 45 loads per hour and it deals with nearly all the rivets which are processed in the plating shop

as well as others to which different finishes are applied. The only types of rivet not degreased in this unit are bifurcated rivets, which are tumbled in dry beech sawdust to remove all surplus lubricating compounds and also to deburr the bifurcation.

The degreased work is then transferred to the Monel cleaning cylinders. These, as also are the plating barrels, are divided into three compartments to assist in the segregation of the various types of work being processed. The work is distributed into these compartments by means of a sliding hopper at the loading stage. The load in a cleaning cylinder is 140 to 160 lb. for the nickel plating line and 160 to 240 lb. for the cyanide line.

The work is then given a soak in a hot alkaline cleaner (180° F.) for 6½ minutes followed by a 3½ minute cold rinse. The alkaline-cleaner tank, which is steam heated, is fitted with an overflow weir, a grease collecting chamber and a circulating pump. Grease is removed at regular intervals when the tank is empty of work. The grease which rises to the top of the cleaner solution flows over the overflow weir into a grease collection chamber equipped with an adjustable grease removal outlet.

Fig. 7.—A general view of the two new lines, the bright nickel line being on the right, the three-partition stainless steel hoppers for dividing the load from the cleaning cylinders into the three partitions of two plating barrels are clearly visible in the foreground.





Fig. 8.—Part of the load from a cleaning cylinder being transferred to a plating barrel.

From this chamber the cleaner is recirculated by a cast-iron pump into spray pipes situated opposite the weir. These sprays assist in washing the grease over the weir.

After rinsing, ferrous components are subjected to a 15-second pickle in 10 per cent cold hydrochloric acid while non-ferrous components are pickled for 15 seconds in 10 per cent cold sulphuric acid, followed in each case by a two-minute cold rinse.

Work is traversed along both the cleaning and plating lines on a monorail on which travels a

hoist with power lift and traversing contacts supplied by George W. King Ltd. The hoist, which is controlled by pendant push-button, has a traverse speed of 100 ft. per min. and a lifting speed of 30 ft. per min. After lifting a barrel from a tank there is a pause to allow the major portion of the liquid to drain back, before it is lifted to the full extent of the hoist, approximately 4 ft. above the solution. This normally ensures ample time for complete draining of the barrel before moving to the next station, thereby keeping drag-out to a minimum.

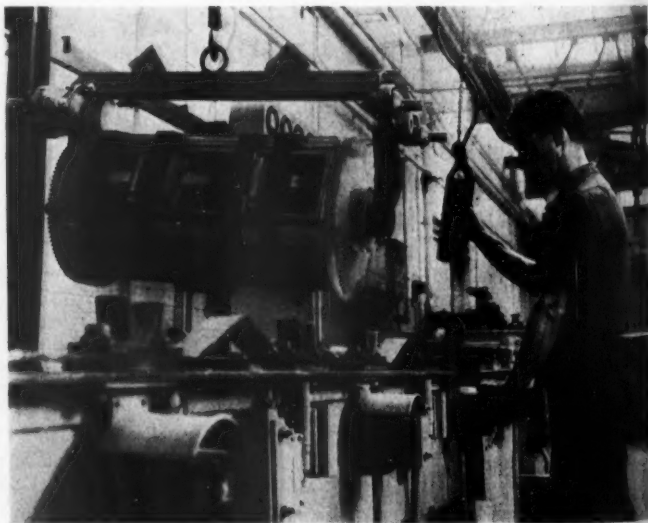


Fig. 9.—Work being processed through the bright nickel line.

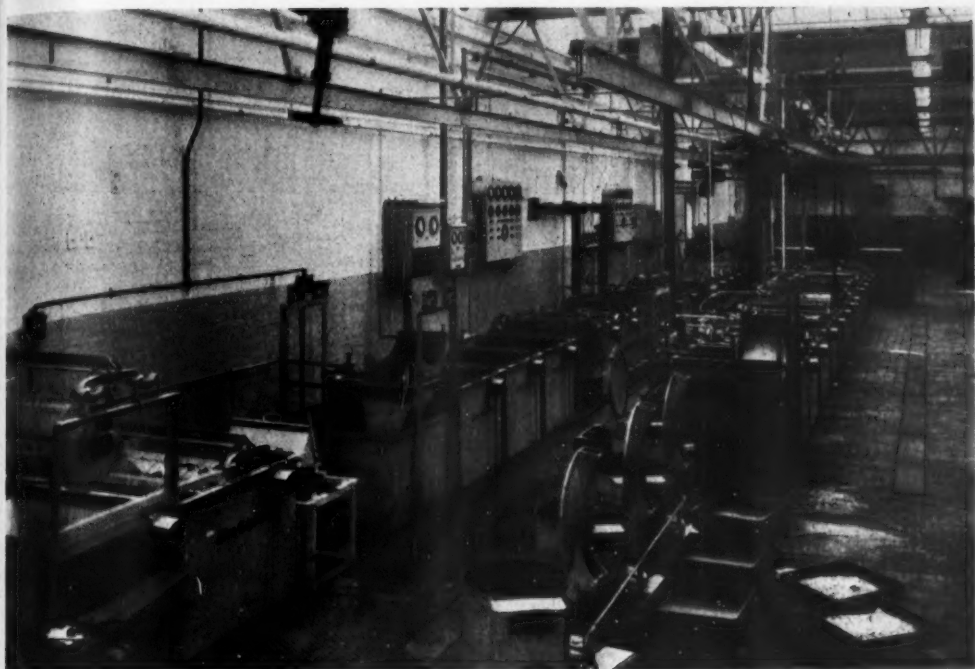


Fig. 10.—View of the plating shop from the unloading end of the lines showing part of the battery of centrifugal driers in the centre foreground.

Plating Lines

After the cleaning cycle the work is discharged from the Monel cylinders into a stainless steel chute specially designed for dividing the load into two plating barrel loads (the cleaning cylinders carry twice the load of plating barrels). The empty cylinders are returned for loading and the transfer chute is lifted by a hoist, discharging half its load into the three compartments of a Perspex plating barrel. When the first barrel has been filled it is moved to the required plating tank and the second barrel is positioned under the chute. By lowering the chute and raising it again the second half of the load is transferred to the barrel.

Bright Nickel Line

Dealing first with the bright nickel line, this uses an Efco-Udylite 31H solution modified for producing a bright finish with good tarnish resistance. It is a solution with the high conductivity necessary for barrel plating, control being simply effected by analysis and ampere-hour factor.

In order to meet the specialized needs of the type of work being processed, some modifications were necessary to the standard type of barrel

normally supplied by the company. In addition to dividing the barrels into three compartments, instead of the usual two, it was also found that the customary $\frac{1}{4}$ -in. diameter hole was too large to retain some of the smaller items being processed. A smaller hole was therefore provided, but this proved insufficient to carry the very high current needed. A final solution of the problem was achieved by counter-boring the holes with a larger diameter to within a very small distance of the interior surface.

Two nickel tanks are operated in parallel, a load of 70 to 80 lb. of work acquiring a thickness of 0.0002 to 0.0003 in. at 140° F. in 66 minutes with a current of over 300 amp.

In the early days of operation of the plant some difficulty was experienced in getting the nickel to throw adequately down the tube of tubular and semi-tubular copper rivets. This trouble was however, quickly traced to insufficient cleaning of this area and has since been completely corrected by increasing the caustic-soda concentration of the alkaline cleaner.

Also, in order to eliminate the familiar type of staining, which occurs after drying, a dip containing 4 oz. per gal. of sodium cyanide was incorporated after the first rinse.



Fig. 11.—Work for plating in bright zinc, seen here being removed from the rinse tank, is processed in an Ebonite barrel and not Perspex.

As a further precaution against staining, in the case of deep tubular rivets, the work, after unloading from the plating barrel, is transferred to a single-compartment steel barrel which is immersed in de-watering oil. When all moisture has drained from this barrel the work is unloaded into a perforated basket and transferred to the centrifugal driers. Work which is not subjected to the de-watering oil treatment is handled by an unloading unit which separately discharges each compartment of the plating barrel into perforated baskets, which are immersed in running water,

thus providing a further rinse stage. From these baskets the work is transferred to the centrifugal driers. These driers are of two types, the older models being steam heated, the more recent ones being self-contained electrically heated ones supplied by R. Cruickshank Ltd.

Cyanide Line

The metals plated in the cyanide line are cadmium, copper, brass and zinc, while tin is deposited in the line from a conventional sodium-stannate solution. The general operating details of these

Fig. 12.—The unloading unit at the end of the bright nickel line showing the sliding hopper which transfers the load separately from each compartment of a plating barrel to baskets immersed in the rinse tank.



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TABLE I
Operating Conditions of Cyanide Plating Line.

Coating	Type of Solution	Temp. °F.	Time of Plating Min.	Thickness of Deposit in.	Remarks
Tin	Sodium Stannate	160	70	0.0001 to 0.0002	
Cadmium	Normal Cyanide	80	70	0.0002 to 0.0003	Acid dip after plating.
Copper	Normal Cyanide	120	70	0.0001 to 0.0002	
Brass	Cyanide with NaHSO ₃	85 to 90	70	0.0001	70/30 alloy anodes.
Zinc	Cyanide with brightener.	65 to 80	70	0.0002 to 0.0003	Ebonite barrel necessary.

baths are shown in Table I. In most cases conventional types of solution are used without the addition of brighteners as the burnishing action of the barrel is sufficient to give a reasonable lustre.

The brass solution used with 70/30 brass anodes, contains small additions of sodium bisulphite to improve the lustre of the deposit, and a small amount of brightener is also added to the zinc solution. As Perspex is not satisfactory for use in a bright-zinc solution, the barrel used in this tank is made of ebonite. All the solutions are carefully controlled by analysis. Freedom from staining on the cadmium-plated work is ensured by provision of a brief after-plating acid dip.

Due to the very porous nature of the surface of much of the work passing through the copper bath, considerable trouble was encountered when the line was first set up, with spotting out on the copper plate. This defect was found to be exaggerated by the presence of contaminants in the solution, iron being a notable offender in this connexion, and also by the use of too low a current density. The removal of metallic contaminants and the careful control of the size of work loads, coupled with the use of an after-plating chromic acid dip, has largely eliminated this defect.

Electrical Equipment and Controls

All the barrels are rotated during plating through a motor and gear box by a pinion drive which provides for a rotation speed of 5 r.p.m., except in the case of the copper tanks where this has been increased to 11 r.p.m. to provide extra burnishing effect.

Special control panels are provided for the two 5-stage nickel tanks to enable accurate time control to be obtained on all plating barrels for thickness of deposit. Each panel carries five ammeters, giving individual readings for each barrel, and one voltmeter. Below each ammeter is situated a time clock scaled 0-100 minutes which can be

preset to any time required within this range. Below each timer are grouped three pilot lights with red, yellow and green distinctive lamp glasses.

Within the contact on the tank rim angles is housed a plunger connected to a limit switch. On placing the barrel in position for plating the appropriate timer is automatically started and the yellow light switched on, indicating that the barrel is plating. At the end of the desired plating period the yellow light is switched off and the green light switched on to indicate to the operator that the minimum plating time has been reached, at the same time the clock re-sets to zero ready for the next plating process. On removal of the barrel all lights are extinguished. Should the operator remove a barrel before the desired plating time has been reached a red light is switched on and a klaxon hooter sounds, which enables the shop foreman to identify the load that has not received its full plating time and can, therefore, withdraw it from the line. This is primarily introduced for the control of specification plating and not for the normal run of commercial plating. Each process and rinse tank is fitted with push-buttons to control the operation of the motor and gearboxes at the opposite end of the tank.

A further control factor is the provision of ampere-hour meters on both the nickel plating bus-bar circuits. The readings on these meters serve as a guide for the regular and controlled addition of brighteners.

Plating current is supplied by a battery of rectifiers situated in an adjoining bay. The total amount of power required by the plating installation, including all drives, pumps, etc., is approximately 240 kVa and the whole plant is operated with a labour staff of nine.

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A Quarterly Survey of some of the Features in Finishing Literature from Abroad

by SCRUTATOR

ALTHOUGH 'electroless' plating processes have not yet been received in this country with the same enthusiasm as in America where electroless nickel deposition is now claimed to be firmly established on a commercial basis, two new American developments, which increase their fields of application, have recently been announced and are of considerable interest. The first concerns the possibility of depositing nickel on non-metallic surfaces such as polystyrene. It is well known, of course, that using the classical type of bath which normally consists of a hot buffered nickel salt solution and employs sodium hypophosphite as the reducing agent, nickel deposition will only occur on certain metallic surfaces. Catalytic metals known to initiate this include Fe, Ni, Co, Al, and Pd; Pearlstein(1) has found that polystyrene and other non-metallic surfaces can be made 'active' for electroless nickel deposition by simple immersion in a palladium-chloride solution. A satisfactory treatment is stated to consist of immersion for 2 minutes in a 0.1 gm. per litre palladium-chloride solution at 125°F. (pH 3.8-4.8). If, however, the polystyrene is first given a stannous chloride pre-dip, the palladium chloride can then be operated at room temperature over the wider pH range 0.9-4.2. Other materials which can be treated include quartz, wood, graphite, bakelite, titanium, tungsten carbide, cork, etc. The second development is the electroless deposition of chromium. According to West(2) ductile, tightly adherent, grey chromium coatings which can be readily brought to a bright finish by buffing or tumbling can be deposited at a rate of about 0.0001 in. per hour on steel or copper and brass. A similar cleaning procedure as for electroplating is recommended, and for the non-ferrous metals a hot solution (160-190°F.) containing sodium citrate, sodium hypophosphite, chromium fluoride (CrF_3) and chromium chloride (CrCl_2) is employed. For steel the bath also contains sodium hydroxide and glacial acetic acid. The coatings are formed more readily on copper and brass than on steel, but as catalytic initiation is necessary to start deposition a steel part must be introduced along with the non-ferrous material. It is suggested that the particular field of application for this process is the barrel plating of small parts.

Waste Not—Want Not

The treatment of metal finishing wastes continues to be a subject of rapidly increasing importance. There is still, however, far too little attention given to the control and operation of water rinsing operations, and the amount of water and hence money needlessly wasted is considerable. Until recently, automatic plating machines were in most cases fully automatic—except for the rinse tanks. It is gratifying to note, therefore, the introduction in America of the Solubridge(3), which is an automatic conductivity controller. This instrument, which incorporates an electronic Wheatstone bridge circuit, measures conductivity and actuates a solenoid valve. The total chemical concentration of a rinse can thus be maintained at any preset value since the valve will only allow water to flow when this concentration is exceeded. For essentially neutral salts, a conductivity of 500 microhms corresponds very approximately with a concentration of 0.1 oz. per gall. and a conductivity increase corresponding to this concentration, in addition to the salts already present in the 'tap water,' is in general considered to be a safe level for most plating rinses.

Rejects are a different kind of plating waste! Some interesting work on the use of spectrographic plating solution analysis to reduce these has been reported by Howard(4). Poor adhesion of electrodeposited nickel (average 0.001 in.) on jet engine components from both automatic (Udylite strike/Watts bath) and manual (Woods high-chloride strike/Watts bath) lines was traced to impurities such as Cu, Fe, Zn and Cr. As little as 0.02 gm. per litre Cu caused complete lack of adhesion. A spectrographic method of analysing the plating baths, strikes and acid dips for these contaminants was evolved and tested over a period of eight months. It proved most satisfactory and as a result rejects due to poor adhesion dropped from 3-5 to 0.1 per cent. The method based on the rod technique consists essentially of evaporating 0.05 ml. of the diluted plating solution under carefully controlled conditions on a graphite rod electrode and uses either an alternating current spark or an over-damped condenser discharge. Since the nickel content of

(Continued in page 446)

Some Investigations into the ACID PICKLING of MILD STEEL

by D. JACKSON, B.Sc., A.R.C.S., A. J. STEDMAN, M.A., A.R.I.C.
and R. V. RILEY, Ph.D., B.Sc., F.I.M.

(A Paper presented to the International Enamelling Congress, Leamington Spa, October, 1955)

Introduction

It appears to be generally agreed that although enamelling is still very much of an art it should, as far as possible, be helped along by the application of scientific principles. This has encouraged the authors to present certain results from experimental work on the pickling of steel. These results have been accumulated from researches carried out from time to time over a period of several years.

Each investigation was usually started to examine some small facet of the subject and because of this piecemeal approach few literature references have been given to the excellent published work of other authors. Reviews of the literature have been made frequently elsewhere.

The work cannot be regarded as complete for it seemed that for every test carried out the results suggested at least a further two tests which might usefully be performed.

Only a small proportion of the investigations were carried out with a subsequent vitreous-enamelling operation in mind but nevertheless it is hoped that the paper may prove useful to enamellers in their day-to-day practice.

The experiments were carried out in the laboratory under "controlled" conditions. That is to say that every attempt was made scientifically to control the known variables. But in this field of work one test-piece often differs markedly from its neighbour cut from the same sheet: therefore, it was not possible to reduce experimental error to a desirable level but statistical methods have helped in assessing the results.

The first part of the paper is an account of some experimental work which was carried out to compare the characteristics of 10 per cent sulphuric acid with 20 per cent hydrochloric acid as pickles for mild steel and to study the effects of variables such as temperature, inhibitors and ageing of the pickle upon the process of pickling. In this particular case the object of pickling was the removal of scale with minimum attack on the metal for the subsequent operations of spot welding, painting or electrodeposition.

The second part describes work carried out to study the effects of previous alkaline cleaning on the process of pickling.

The third part gives some results obtained in a short study of the nickel-dip process and some other work which was done to improve the surface condition of steel after pickling.

PICKLING OF MILD STEEL IN SULPHURIC- AND HYDROCHLORIC-ACID PICKLING BATHS

Solutions of 10 per cent by volume (1.84 S.G.) sulphuric acid used at 70-80° C. and 20 per cent by volume (32 per cent W/W) hydrochloric acid used at 40-50° C. were adopted as standard pickles.

In practice the concentration of acid in a pickle is maintained by continual additions of fresh acid so that as a solution becomes used it contains more and more iron salts. For the experimental work the baths were artificially aged by the addition of ferrous sulphate or ferrous chloride. Proprietary inhibitors were added to the baths in varying amounts as required.

The Removal of Heat-treatment Scale

The following procedure was adopted to produce standard test-pieces for descaling tests:

- (i) Test-pieces were $2\frac{1}{2} \times 3$ in. \times 16 swg mild steel B.S. S3, i.e. 90 sq. cm. surface area.
- (ii) Test-pieces were degreased in a hot alkaline degreaser consisting of 40 gm per litre sodium hydroxide and 0.2 to 0.4 per cent sodium alkyl sulphate at 80-100° C.
- (iii) A normalizing heat treatment in an electric muffle furnace at 800-850° C. for 10 minutes followed by air cooling.

Tables I and II show the time needed to descale a standard test-piece under various conditions in sulphuric and hydrochloric acids respectively.

In both pickles it was found that the presence of inhibitor in varying amounts had no noticeable effect upon the rate of descaling.

The effect of temperature was more or less as

TABLE I

Descaling tests in 10 per cent sulphuric acid using proprietary Inhibitor "A"

Amount of Inhibitor g/l of Conc. Acid	Temp. °C.	Ferrous Sulphate added $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$ g/l	Age of scale in days	Time to commence descaling, min.	Time to complete descaling, min.
Nil	80	0	Pickled at once	0 = less than $\frac{1}{2}$ min.	1½
Nil	80	0	" " "	0	2½
Nil	80	0	" " "	½	1½
3	80	0	" " "	0	2½
3	80	0	" " "	0	2
3	80	0	" " "	0	2
3	80	0	" " "	½	1½
6	80	0	" " "	0	2
6	80	0	" " "	½	1½
6	80	0	" " "	½	1½
24	80	0	" " 4	0	1½
24	80	0	4	0	1½
24	80	0	6	0	1½
24	80	0	7	0	1½
24	80	0	8	0	1½
24	70	0	4	0	3½
24	70	0	4	0	3½
24	70	0	6	0	3
24	70	0	7	0	3
24	70	0	8	0	3½
12	70	400	20	1	4½
12	70	400	20	1	5½
12	70	400	20	1	5

TABLE II

Descaling tests in 20 per cent hydrochloric acid using proprietary Inhibitor "B"

Amount of Inhibitor g/l of Conc. Acid	Temp. °C.	Ferrous Chloride as Fe g/l	Age of scale in days	Time to commence descaling, min.	Time to complete descaling, min.
Nil	40	0	Pickled at once	0 = less than $\frac{1}{2}$ min.	4
Nil	40	0	" " "	1½	5
Nil	40	0	" " 1	2	5
Nil	40	0	1	0	5
Nil	40	0	1	1	5
Nil	40	0	1	2	5
2.5	40	0	1	2	5
2.5	40	0	Pickled at once	2½	6
2.5	40	0	" " "	2	5
2.5	40	0	" " 1	3	6
2.5	40	0	1	3	6
5.0	40	0	Pickled at once	2	7
5.0	40	0	1	2	6½
5.0	40	400	Pickled at once	2	9
5.0	40	400	1	2½	10
Nil	50	0	Pickled at once	1	3½
Nil	50	0	" " "	1	3
2.5	50	0	" " 1	1	2½
5.0	50	0	Pickled at once	0	1½
5.0	50	0	" " "	1	4½
5.0	50	0	" " 1	1½	4
5.0	50	400	Pickled at once	1	7
5.0	50	400	1	2	7

expected namely that a 10° C. rise in temperature approximately halved the time of descaling.

The effect of loading the baths with iron salts is to increase substantially the time needed for descaling, in the case of sulphuric acid by about 70 per cent and in the case of hydrochloric acid by about 130 per cent. The age of the scale itself has little or no effect on the descaling time in either pickle.

The main conclusion to be drawn from these results is that hydrochloric acid must be operated at as high a temperature as 50° C. for it to remove scale at the same rate as sulphuric acid operated at 70° C.

It will be seen from these observations that the authors are in disagreement with the views expressed by G. & A. Delattre* to a previous conference of the Institute. These views were that with sulphuric acid there is a troublesome slowing down of the speed of pickling with increasing ferrous-sulphate concentration in the pickle whereas on the other hand with hydrochloric acid growing amounts of ferrous chloride in the pickle have little effect on the pickling speed.

The Removal of Gas Welding Scale

Mild-steel test-pieces were degreased by the standard procedure and were lap-welded with a fillet down both sides. The specimens were allowed to cool in air thus providing a thin tenacious layer of scale.

Table III gives comparative observations on the descaling of the welded test-piece in sulphuric acid and in hydrochloric acid. The acid pickles were in each case inhibited and artificially aged. The baths were run at 70°C. for sulphuric acid and 50°C. for hydrochloric acid. There was no perceptible difference in descaling behaviour, once again showing that hydrochloric acid does not compete with sulphuric acid at 70°C. unless the hydrochloric is at 50°C.

The Loss of Weight of Steel during Pickling and the Effect of Inhibitors

The loss of steel during descaling is a matter of some importance since it has a bearing upon the economy of the process of pickling. The following procedure was adopted:—

- (1) Test-pieces cut 2½ × 3 in. × 16 swg all from the same sheet of steel B.S. S3.
- (2) Specimens degreased in trichlorethylene vapour followed by immersion in a hot alkaline degreaser (as in previous experiments).
- (3) Specimens etched lightly in an uninhibited acid pickle for 30 seconds.
- (4) Rinsed in running water.

*G. & A. Delattre: "Modern Aspects of Steel Pickling." *Proc. Inst. Vitreous Enamellers*, 1952-54, 11, 110-114.

TABLE III
Descaling after gas welding

Time min.	10 per cent sulphuric acid + ferrous sulphate 400 g/l. 70°C.	20 per cent hydrochloric acid + inhibitor + ferrous chloride Fe = 400 g/l. 50°C.
½	Slight effervescence started	Slight effervescence started
1	Small scale particles moving from edge	Small scale particles moving from edge
1½	Light scale removed	—
2	—	Weld scale starting to dissolve
2½	—	Light scale still dissolving
3	Weld scale starting to dissolve	Light scale dissolved
7	Weld scale nearly removed	Weld scale nearly removed
8-10	Scale removed	Scale removed

- (5) Dipped in an alkaline rust-preventing solution
- (6) Swilled in water.
- (7) Immersed in acetone, dried and cooled.
- (8) Weighed.
- (9) Pickled for precisely 15 minutes at working temperature.
- (10) After-treatment as in operations (4) to (8) inclusive.

The experimental results with sulphuric acid are summarized in Table IV which indicates the mean loss in weight recorded in milligrams after pickling in inhibited 10 per cent sulphuric acid. Experiments were carried out with fresh sulphuric acid and also a pickle with progressively increasing additions of ferrous sulphate to simulate the progressive ageing of a works pickle. Each figure in the Table is the mean of at least three results determined simultaneously. Difficulty was experienced in these experiments as some anomalous results were obtained. These are marked with an asterisk. On repeating, it proved impossible to obtain results giving a higher degree of correlation and, therefore, it is difficult to give a quantitative interpretation to the results. The Table does, however, indicate the general trend.

With sulphuric acid the rate of etching gradually rises as the pickle becomes aged with an increasing concentration of ferrous sulphate. The efficiency of inhibition for a given concentration of inhibitor falls with increased iron content.

The efficiency of inhibition is defined as follows:—

$$E = \frac{W - W^1}{W} \times 100 \text{ per cent}$$

where W is the loss in weight of a test-piece in a solution without inhibitor and W¹ is the loss in

TABLE IV

Mean loss in milligrams in 10 per cent sulphuric acid using proprietary sulphuric-acid Inhibitor "A"—15 minutes immersion—90 sq. cm. panel surface area.

Bath	Amount of Inhibitor g/l of Conc. Acid	70° C.					80° C.				
		Fresh	50 g/l FeSO ₄ ·7H ₂ O ⁴	100 g/l	200 g/l	400 g/l	Fresh	50 g/l FeSO ₄ ·7H ₂ O ⁴	100 g/l	200 g/l	400 g/l
A	Nil	420	500	1,170*	710	850	1,090	1,470	1,550	1,440	1,360
B	3	37	80	110	110	400	130	290	520	310*	470*
C	6	22	52	74	40*	200	46	78	230	74*	480
D	12	20	35	56	39*	140	22	69	110	190	340
E	24	11	17	35	52	120	17	43	74	100	130

*Apparently anomalous result.

weight of an exactly similar test-piece in the same solution with inhibitor. The results obtained show that in the time necessary (10 minutes) for descaling of the test-pieces completely in the 10 per cent sulphuric acid pickle at 70°C. with the optimum amount of inhibitor (12 gm. per litre), the attack upon the base steel is negligible, whatever the age of the pickle.

The results obtained with hydrochloric acid using the same experimental technique are given in Table V. The general conclusions are also that as the concentration of iron in the pickle rises, the inhibitor becomes less efficient but unlike sulphuric acid the effect of moderate ageing to 50 gm per litre Fe is to reduce the rate of attack compared with a fresh solution.

This is a somewhat surprising result as it has hitherto been generally accepted that the presence of moderate amounts of iron in a hydrochloric acid pickle gives an increased rate of pickling (etching).

Above this level of iron concentration the rate of attack rises until at 400 gm. per litre Fe in an uninhibited solution the rate of attack is approximately the same as in the fresh solution whereas in an inhibited solution the rate of attack is considerably more in a fully aged than in a fresh solution.

It is worth noting that with hydrochloric acid even at a temperature as high as 50°C. there is substantially less rate of etching of the steel than

with sulphuric acid at 70°C. in uninhibited baths, even though the speed of scale removal in the two baths is the same.

The table shows that in the time necessary for descaling in 20 per cent hydrochloric acid at 50°C. with the optimum amount of inhibitor (2.5 gm. per litre) there is negligible attack on the steel whatever the age of the pickle.

In the experiments set out in Table VI the sulphuric-acid bath was not aged but contained varying amounts of inhibitor and was worked at 70°C. The test-pieces were immersed for 15 minutes. From the results it would appear that the inhibiting effects of proprietary material and the glue are each independent and that the addition of both materials might be an advantage. Provided sufficient inhibitor or glue is present, phosphoric acid has little inhibiting effect. The inhibiting efficiency of a 15 gm per litre phosphoric acid addition is approximately 50 per cent.

EFFECTS OF PRIOR CLEANING TREATMENTS ON RATE OF PICKLING

Introduction

The work described in this part of the paper arose from a study of degreasing problems using hot alkaline cleaners.

Alkaline cleaners consist usually of mixtures of one or more of sodium hydroxide, silicates, phosphates, carbonates, etc., together with surface-active agents.

TABLE V

Mean loss in milligrams in 20 per cent hydrochloric acid using proprietary hydrochloric acid inhibitor "B" and aged with additions of ferrous chloride—15 minutes immersion—90 sq. cm. panel surface area.

Bath	Amount of Inhibitor g/l of Conc. Acid	40° C.					50° C.				
		Fresh	50 g/l Fe ⁺⁺	100 g/l	200 g/l	400 g/l	Fresh	50 g/l Fe ⁺⁺	100 g/l	200 g/l	400 g/l
A	Nil	70	28	40	30	60	170	57	80	170	170
B	2.5	7	6	20	20	20	13	11	20	35	60
C	5.0	3	1	3	6	10	4	2	10	30	50

TABLE VI

Mean loss in milligrams in 10 per cent sulphuric acid at 70°C., without the addition of ferrous sulphate, with different additions of inhibitors to 1 litre of solution

No.	Inhibitor	Loss in Weight mg	% Efficiency of Inhibition
1	No inhibitor	990	0
2	0.6 g. proprietary sulphuric acid inhibitor A	120	88
3	2 g. glue	130	87
4	1% by volume phosphoric acid	490	50
5	0.6 g. proprietary sulphuric acid inhibitor A	72	93
6	1% phosphoric acid 2 g. glue	75	92
7	1% phosphoric acid 0.6 g. proprietary sulphuric acid inhibitor A	22	98
8	2 g. glue 0.6 g. proprietary sulphuric acid inhibitor A	22	98
	2 g. glue 1% phosphoric acid		

Insufficient rinsing and the picking up of foam on components and pickling baskets can result in a carry-over of some of the ingredients of alkaline cleaning baths into the pickle. It was considered desirable to find to what extent this carry-over could affect the rate of pickling.

Experimental Procedure and Materials

For each experimental condition six panels $2 \times 4 \times \frac{1}{8}$ in. were used.

They were prepared as follows:—

- Thoroughly degreased in boiling orthosilicate solution at 8-oz. per gallon.
- Rinsed in water.
- Immersed in acetone and dried in a stream of hot air.
- Weighed.

After pickling at a constant temperature for the required time, the panels were removed from the pickling bath and treated as follows:—

- Rinsed in cold running water.
- Immersed in acetone and dried in a blast of hot air.
- The panels were weighed to determine the loss in weight on pickling. The loss in weight was taken as an indication of the rate of pickling (etching).

The pickling solutions with the desired additives were brought to equilibrium in a thermostatically controlled bath.

Analytical grade hydrochloric acid, 32 per cent W/W, and sulphuric acid 96 per cent, were used

in the synthetic pickles at 20 per cent by volume and 10 per cent by volume respectively.

In this work anhydrous sodium orthosilicate was the basis of the alkaline cleaner.

The surface-active agents used are described under the appropriate section. Other ingredients in the experimental pickles were sodium chlorate, for increasing the activity of the acid, and electrolytic iron powder for artificially ageing the pickle bath.

Three types of steel sheet have been used. The majority of the experiments were done with deep-drawing-quality steel sheet and the remainder were on ordinary enamelling quality and extra-deep-drawing-quality steel sheet. All the steel specimens were cut from single sheets produced by one manufacturer.

The Significance of Results

With the exception of Table VII the figures given in the Tables for the weight losses on pickling are the means of the losses on at least 3 panels pickled at the same time.

In Table VII, however, the individual weight losses for panels treated together in experiments 1 to 7 are shown. From each set of results the standard deviations $\sigma_{27.5}$ and $\sigma_{32.5}$ have been calculated. The standard deviation on the whole set of results is given by:—

$$\sigma = \sqrt{\frac{(\sigma_{27.5}^2 \times 20) + (\sigma_{32.5}^2 \times 17)}{37}} = 1.9$$

Using this value of σ the differences required between the means of sets of 3 replicates can be calculated for various levels of significance from the expression for Students t :—

$$t = \frac{\bar{x}_1 - \bar{x}_2}{\sigma} \sqrt{\frac{n_1 \times n_2}{n_1 + n_2}}$$

where \bar{x}_1 and \bar{x}_2 are the means of n_1 and n_2 tests respectively or

$$\bar{x}_1 - \bar{x}_2 = \frac{t \times 1.9}{\sqrt{9/6}}$$

From tables the value of t at the 95 per cent significance level with 4 degrees of freedom is 2.78. Thus $\bar{x}_1 - \bar{x}_2 < 4.3$ at an average level of 14.1 for a 95 per cent probability that the two means \bar{x}_1 and \bar{x}_2 are significantly different.

In other words for a 95 per cent probability that 2 sets of 3 results are significantly different the means must lie apart by at least 30 per cent of their average value. For a 90 per cent probability the figure is 23 per cent.

Where more than 3 individual figures are available for giving a mean or where a trend is shown by sets of figures with successive changes in any variable, two means can be closer than this

TABLE VII

Effect of Temperature on 20 per cent Hydrochloric Acid Pickle

30 minutes immersion. "Deep-drawing" steel. With "silica film." 106 sq.cm. panel surface area. Loss in weight in mg.

Expt. No.	27.5°C	Expt. No.	32.5°C
1	11.3, 11.8, 12.5, 14.0, 12.5, 11.4	5	14.5, 15.7, 15.5, 13.6, 13.7, 12.9
2	11.0, 10.1, 9.5, 10.2, 10.7, 9.4	6	19.9, 19.2, 18.5, 20.7, 19.5, 20.3
3	11.8, 12.2, 11.4, 11.5, 11.6, 11.7	7	16.5, 16.5, 16.1, 15.5, 15.7, 15.9
4	14.2, 11.3, 13.6		
	Mean 11.6 $\sigma_{27.5} = 1.29$		Mean 16.7 $\sigma_{32.5} = 2.43$

and still be regarded as significantly different. In these circumstances the authors feel that any result can be considered significantly different from any other result if the mean of one set is more than 20 per cent different from the mean of any other set.

Effects of Silica Film on Steel before Pickling

Inadequate rinsing of an alkaline cleaner containing silicate could lead to the precipitation of a thin gelatinous silica film on components when they pass into the pickle.

For this set of experiments a silica film was artificially precipitated on the test panels before pickling. They were immersed after weighing in a 5 per cent anhydrous sodium-orthosilicate solution at 95° C. for 5 minutes. They were then dipped in cold 10 per cent hydrochloric acid for 10-15 seconds to fix the silica film, dipped in cold water and transferred to the pickle bath. For control purposes the panels were thoroughly rinsed with water to remove all alkali drag-out and then immersed in the pickle.

Table VIII shows the results of pickling under various conditions. Taking the results as a whole the presence or absence of a precipitated silica film on steel appears to make no significant difference to the rate of etching.

The Effect of Surface-active Agents in a Hydrochloric-acid Pickle

Anionic and nonionic surface-active agents are often incorporated in alkaline cleaners. The nonionic surface-active agents are particularly efficient for this purpose but they suffer from the disadvantage that as the solution nears the boiling point they tend to separate out on to the surface of the solution and adhere to components being cleaned. The anionic surface-active agents form particularly stable foams and these also can be

TABLE VIII

Effect of "Silica Film" on Steel During Pickling
20 per cent (by volume) hydrochloric acid for 30 minutes on "deep-drawing" quality steel. 106 sq.cm. panel surface area

Temperature °C	Mean Weight loss in mgms.		Additive Percentage and Type	
	With Silica Film	Without Silica Film		
27.5	11.6	13.0	0.25	None
"	11.2	9.9	0.25	A1
"	9.7	9.7	0.25	A2
32.5	7.5	6.7	0.1	N1
20	3.1	3.1	2.2	Iron

carried over to the pickling solutions.

In some cases one or other of these types of surface-active agents is added deliberately to pickling solutions with the idea of smut dispersal and/or the formation of a foam blanket to reduce spray.

The following types of surface-active agents were investigated as additives to a hydrochloric acid pickle:—

- (1) An anionic condensation product of formaldehyde with sodium naphthalene sulphonate — hereafter described as surface-active agent A1.
- (2) An anionic 40 per cent active sodium dodecylbenzene sulphonate — hereafter described as surface-active agent A2.
- (3) A nonionic condensation product of about 10 ethylene oxide units with a nonyl methyl phenol — hereafter described as surface-active agent N1.
- (4) A nonionic condensation product of about 20 polyethylene oxide units with a saturated fatty acid — hereafter described as surface-active agent N2.

Fig. 1.—Effect of Surface-active Agent N1.

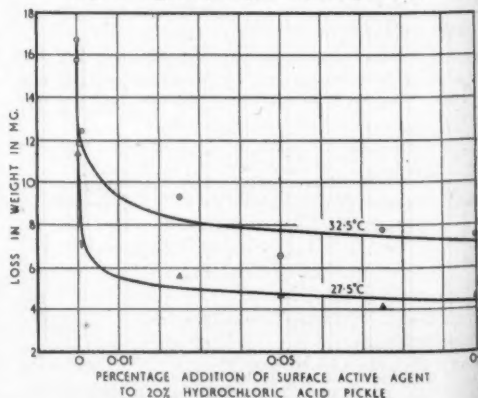


TABLE IX

The Effect of Surface-active Agents added to 20 per cent Hydrochloric-acid Pickle
30 minutes immersion. "Deep-drawing" steel. With "silica film". 106 sq. cm. panel surface area.

Expt. No.	Name	Additive	Conc. %	Temperature	Mean Weight Loss mg.
1	A1	—	—	27.5°	11.6
2		0.025			10.4
3		0.10			10.9
4		0.25			11.2
1	A2	—	—	27.5°	11.6
5		0.025			10.4
6		0.10			8.4
7		0.25			9.7
1	N1	—	—	27.5°	11.6
8		0.001			7.1
9		0.025			5.6
10		0.050			4.7
11		0.075			4.1
12		0.10			4.6
13	N1	—	—	32.5°C.	16.7
14		0.0001			15.8
15		0.0005			11.9
16		0.001			12.4
17		0.025			9.3
18		0.050			6.6
19		0.075			7.8
20		0.10			7.5
21	N1	—	—	34°C.	21.1
22		0.0001			19.1
23		0.0005			14.8
24		0.001			15.3
13	N2	—	—	32.5°C.	16.7
25		0.00025			13.7
26		0.00125			11.0
27		0.125			10.2

Expt. No. 1 is the mean of 21 panels. Expt. No. 13 is the mean of 18 panels.

Table IX shows the effect of varying additions of these surface-active agents to a hydrochloric-acid pickle.

With surface-active agent A2 there appears to be a very slight fall in the rate of etching but even this fall may not be significant for the difference in the figures from minimum to maximum addition is at the limit of the 20 per cent accuracy range.

The presence of surface-active agent A1 appears to make no difference to the rate of pickling.

Surface-active agents N1 and N2 do cause a slight but statistically significant reduction in the rate of etching and the results for N1 at 27.5°C. and 32.5°C. have been plotted in Fig. 1 for greater clarification. A slight increase in the temperature of pickling can easily compensate for the slight inhibiting effect of this type of surface-active agent.

It is considered that variations of temperature and other conditions in shop practice can cause variations in pickling of greater magnitude than

the presence of traces of anionic and nonionic surface-active agents which can, therefore, be regarded as harmless from the practical point of view.

The Effect of Sodium-chlorate Additions to a Hydrochloric-acid Pickle

Depth of etching is thought by some authorities in the enamelling trade to be a necessary adjunct to good adherence of acid-resisting self-mottle enamels. For various reasons it may not be possible to achieve the required rate of pickling, for example by raising the temperature of a hydrochloric-acid pickle or converting to sulphuric acid.

Some experiments, the results of which are given in Table X, were carried out to determine the accelerating effects of additions of sodium chlorate.

The authors do not desire to draw any particular

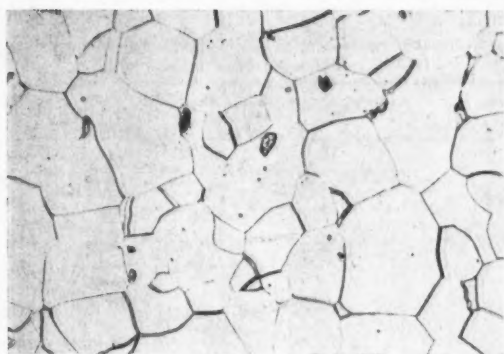


Fig. 2a.—Coarse grain.

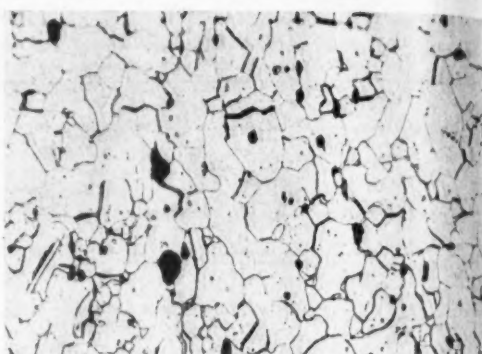


Fig. 2b.—Fine grain.

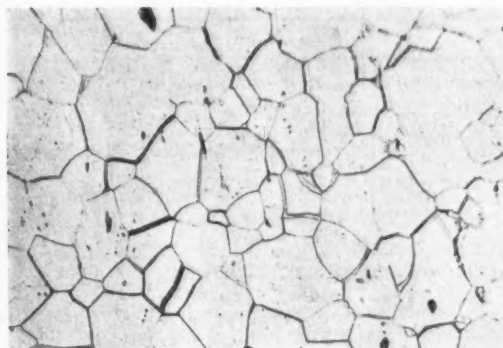


Fig. 2c.—Coarse grain.

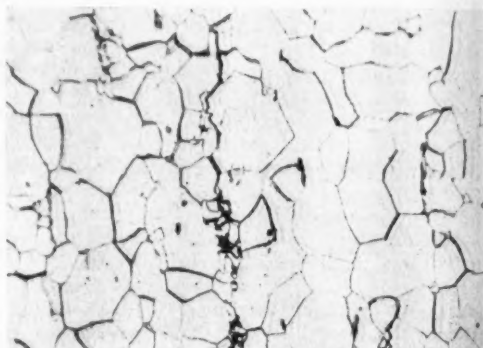


Fig. 2d.—Fine grain.

conclusions from these results which are merely presented as data.

The Effect of Temperature and the Temperature Coefficient of Reaction in Hydrochloric Acid

Table VII shows the results on pickling without

TABLE X

The Effect of Sodium Chlorate added to 20 per cent Hydrochloric-acid Pickle

30 minutes immersion. "Deep-drawing" steel. With "silica film". With 0.001 per cent wetting agent NI. 106 sq. cm. panel surface area

Expt. No.	Temperature	Sodium Chlorate conc. %	Mean Weight Loss mg.
1	32.5°C.	Nil	18.2*
2	"	Nil	12.4
3	"	0.01	15.1
4	"	0.1	18.6
5	"	0.5	595
6	"	1.0	817
7	27.5°C.	Nil	7.1
8	"	0.5	375
9	"	0.1	500

* No. NI addition

additive at 27.5 and 32.5°C. Plotting log mean weight losses against temperature and extrapolating on a straight line gives a weight loss at 25°C. of 9.7 mg. and a weight loss at 35°C. of 20 mg. The temperature coefficient of reaction over 25—35°C. is, therefore, 2.06 and it can be taken that the rate of attack of the hydrochloric acid pickle on steel increases in accord with the well-known effect of temperature on many chemical reactions where 10°C. rise in temperature may be expected to double the rate of reaction.

Table XI shows further results of pickling under a variety of conditions at various temperatures and it will be seen that in general the figures conform approximately to the same pattern.

The Effect of Quality of Steel Sheet

The majority of the experiments were with deep drawing-quality mild-steel sheet but some experiments were carried out using ordinary enamelling-quality mild-steel sheet and some using extra-deep-drawing-quality mild-steel sheet. A direct comparison of the weight losses on pickling of the three different grades is shown in Table XII.

TABLE XI

Effect of Temperature on 20 per cent HCl Pickle
30 minutes immersion. "Deep-drawing" steel. With
"silica film". 106 sq. cm. panel surface area.

Expt. No.	Additive	Mean Weight Loss in mg.		
		27.5°C.	32.5°C.	34°C.
1	0.0001% NI		15.8	19.1
2	0.005% NI		11.9	14.8
3	0.001% NI	7.1	12.4	15.3
4	0.205% NI	5.6	9.3	
5	0.050% NI	4.7	6.6	
6	0.075% NI	4.1	7.8	
7	0.100% NI	4.6	7.5	

Experiment No. 1 carried out at 20°C. showed that the rate of attack is lower for extra-deep-drawing quality than for ordinary enamelling grade. This result was in accordance with expectations as it was presumed that extra-deep-drawing steel would have a coarser grain structure.

However, later in the work during some experiments on nickel dip, further results were obtained which are shown in experiment 2. In this case the entirely unexpected effect is found that the rate of attack was greater on the so-called extra-deep-drawing quality. Photomicrographs of sections of these test pieces were taken in an endeavour to find an explanation for this result. Unfortunately it was found that if the sections were examined in one place the extra-deep-drawing quality could be shown to have a finer grain than the other grades, but if the sections were reground and repolished exactly the opposite effect could be seen. This means that the variations in crystal size from point to point within one quality of steel are far greater than the variation in crystal size from quality to quality.

Photomicrographs showing this are given in Fig. 2, a, b, c and d.

Regrettably there has not been sufficient time for the authors to study more comprehensively the effect of quality of steel on rate of pickling.

Sulphuric Acid

For comparison purposes Table XIII shows some weight losses obtained in 10 per cent sulphuric acid. It will be seen that the rate of

TABLE XIII

Effect of 10 per cent Sulphuric-acid Pickle Under Various Conditions
66°C. "Deep drawing" steel. No "silica film". 106 sq. cm. panel surface area

Expt. No.	Time Min.	Additive	Mean weight loss in mg.
1	5	—	51
2	10	—	140
3	15	—	267
4	10	0.001% NI	49
5	10	0.1% Al	44

attack on steel is of a far greater order with hot sulphuric-acid solutions than with the cooler solutions of hydrochloric acid and that surface-active agents do have a slight inhibitory effect.

THE SURFACE CONDITION OF STEEL AFTER PICKLING

Nickel-dip Treatment

The process of nickel-dip consists of coating steel with a thin layer of nickel by galvanic displacement from a hot solution of nickel sulphate.

The degree of surface roughening resulting from varying rates of steel attack during pickling is thought to affect the weight of nickel taken up by the steel. It was desirable, therefore, to investigate the action on the pickling bath of surface active agents and other possible contaminants which might come from the alkaline cleaner section in relation to the ultimate effect on the amount of nickel deposited.

The specimens which were nickel-dipped after pickling were treated as follows:—

- Immersed for 20 minutes at 80°C. (C.180°F.) in a bath containing nickel-sulphate-hexahydrate solution at 6.25 gm. per litre (1 oz. per gal.), the pH being adjusted to between 3—3.5 before immersion of the test panels.
- The panels were dipped in 1 per cent cold hydrochloric acid.
- Rinsed in water, immersed in acetone and dried.
- The nickel coating was stripped from the

TABLE XII

Effect of Grade of Steel Sheet on 20 per cent Hydrochloric-acid Pickle
30 minutes immersion. 106 sq. cm. panels. Weight loss in mg.

Expt. No.	Temperature	Ordinary Enamelling Grade	Deep Drawing	Extra-Deep Drawing
1	20° C.	Mean 6.7	Mean 4.7	Mean 4.5
2	30° C.	8.0, 10.1, 9.4, 12.6, 11.4, 12.1, 8.0, 13.2	11.5, 11.6, 17.5	23.9, 17.6, 22.6
		Mean 10.6	Mean 13.5	Mean 21.4

TABLE XIV
Results of Nickel-dip Treatment

20 per cent Hydrochloric-acid or 10 per cent Sulphuric-acid Pickle. "Deep-drawing" quality steel. 106 sq. cm. panel surface area.

Expt. No.	Pickle					Nickel Dip mg/sq. cm.
	Type	Time min.	Temperature	Additive	Wt. loss mg.	
1	H ₂ SO ₄	5	66°C.	—	51	0.12
2	"	10	"	—	140	0.14
3	"	15	"	—	267	0.15
4	"	10	"	0.001% NI	49	0.14
5	"	10	"	0.1% AI	44	0.10
6	HCl	30	27.5°C.	—	13.1	0.13
7	"	"	"	0.001% NI	7.1	0.12
8	"	"	"	0.001% NI	375	0.18
9	"	"	"	0.5% NaClO ₃	500	0.36
10	"	"	"	0.001% NI	—	—
11	"	"	32.5°C.	1.0% NaClO ₃	22.7	0.11
12	"	"	"	0.001% NI	595	0.48
	"	"	"	0.5% NaClO ₃	817	0.35
	"	"	"	0.001% NI	—	—
	"	"	"	1.0% NaClO ₃	—	—

steel panel in a solution of *aqua regia*.

- (v) Nickel determined by analysis by the method given in the Appendix.

The experimental procedure was to take six panels, pickle them together, use three to determine the weight loss on pickling and the other three to determine the amount of nickel deposited in nickel dip.

It is generally expected that the weight of nickel deposit should be about 0.12 to 0.15 mg. per sq. cm. for satisfactory adherence of acid-resisting self-mottle enamels and it will be seen from Table XIV that this quantity of nickel was obtained with a good margin of safety after pickling for 10 to 15 minutes in hot sulphuric acid and was just obtainable with a 30-minute pickling in hydrochloric acid at 27.5 to 32.5°C.

It can be observed from experiments 4 and 7 that the presence of surface-active agent NI, while slightly inhibiting the rate of attack of both sulphuric and hydrochloric acids, did not significantly affect the weight of nickel deposited in the subsequent nickel-dip.

In an endeavour to assess the effect of a relatively large increase in the amount of etching and roughness of the steel quite large quantities of sodium chlorate were added to the hydrochloric acid pickle.

It was found that only when very large weight losses in pickling were achieved with the use of sodium chlorate as accelerator could the quantity of nickel deposited under standard nickel-dip conditions be materially increased. The general effect of an increase in the rate of pickling of

mild-steel sheet on the ensuing nickel-dip process appears to be small. The standard level of 0.12 to 0.15 mg. per sq. cm. is approached in almost every case even though the weight losses on pickling vary over a wide range.

The authors realize that these results are only scratching the surface of the subject of the variations which can be made with nickel dip and prior pickling. Each test, however, was quite time-consuming and they have not been able to explore more widely.

Brightening Dips

Pickling steel in either sulphuric acid or hydrochloric acid always produces a loose grey-black residue on the surface which can, however, be removed by swilling with a light surface rub. Attempts were made to brighten the surface of the steel after descaling using nitric acid and other acidic conditions.

In Table XV are summarized a number of acid conditions which were used in an effort to brighten the surface of the steel after descaling. Solutions 3, 4 and 5, 40-80 per cent by volume nitric acid, specific gravity 1.42, at room temperature, gave a violent reaction. A dip of approx. 15 seconds followed by rinsing in running water left the surface bright but a light brown stain was produced which adhered loosely to the surface. A momentary dip in the pickle removed the stain. Solution 2, 20 per cent nitric acid at 80°C. produced the same effect after one minute. Unfortunately, however, 40-80 per cent nitric acid is not a very practical solution to use in a produc-

TABLE XV
Treatments tried for "brightening" after descaling

No.	Solution	Temp. °C.	Observations
1.	10% nitric acid (S.G. 1.42) by volume	20 40 60 80	Mild to vigorous effervescence. Loose deposit unaffected.
2.	20% nitric acid	20 40 60 80	Vigorous action. Loose deposit removed after 1 min.
3.	40% nitric acid	20	Extremely violent
4.	50% nitric acid	20	action. Loose deposit
5.	80% nitric acid	20	removed in 15 seconds.
6.	85% nitric acid	20	No effervescence, partial
7.	90% nitric acid	20	removal of loose
8.	100% nitric acid	20	deposit.
9.	20% Phosphoric acid 20% Nitric acid	20 40 60 80	No apparent action. Loose deposit un- affected.
10.	10% Phosphoric acid 5% Nitric acid	20	
11.	45% hydrochloric acid 5% nitric acid with and without inhibitor	60	No apparent action. Loose deposit un- affected.
12.	4% sodium hydroxide 1% Anionic wetting agent	90	No action. Cathodic treatment: No action
13.	30% (by volume) sul- phuric acid Anodic etching 100 amp per sq. ft.	20	Loose deposit removed in 2 min. leaving sur- face suitable for electro- deposition.

tion process. Solutions 6, 7 and 8, 85-100 per cent nitric acid, were partially successful for brightening without having any dissolving action on the steel.

Since the grey deposit after pickling could be mopped off, an attempt was made to remove it with an alkaline cleaner but this was unsuccessful whether the alkaline cleaner was used as an immersion bath or for cathodic cleaning.

Anodic etching in sulphuric-acid solution, condition 13 removed the deposit leaving the surface suitable for electrodeposition.

General Discussion of Results

The experiments show that 10 per cent sulphuric acid at 70°C. is roughly equivalent in pickling power to 20 per cent hydrochloric acid at 50°C., both in respect of annealing scale and gas-welding scale. An increase of 10°C. in bath temperature doubles the rate of acid attack in each case.

It is confirmed within the limits of the experiments that acid inhibitors, while limiting the rate of dissolution of steel, have no noticeable effect on the rate of scale removal. The efficiency of inhibitors is diminished slightly by the ageing of pickling baths but under the usual works condi-

tions this can be neglected. In both sulphuric-acid and hydrochloric-acid pickles the presence of large amounts of dissolved iron increases the time necessary for scale removal.

Steel which has been degreased in an alkaline silicate solution is pickled at the same rate whether or not the surface has been rinsed free from deposited "silica" film.

Traces of nonionic surface-active agents, frequently constituents of commercial alkaline silicate cleaners, have been found to slow down slightly the rate of pickling (etching), but a small increase in bath temperature is sufficient to correct this. Variations in shop practice and local variations in the surface of the steel sheet may affect pickling rates more profoundly than these surface-active agents carried over from the cleaning bath. Therefore they can be considered harmless from the practical point of view.

Carry-over of the components of an alkaline silicate cleaner into the pickling tank has no apparent effect on the weight of nickel deposited in the subsequent nickel dip.

Throughout this paper the "significance" of results has been constantly borne in mind and for this reason the authors are reluctant to draw too detailed conclusions from the practical work carried out. Despite the care which was exercised at all stages of the work it is clear that even with the best control, some variables remained uncorrected which prevented the close duplication of experimental results so often (quite wrongly) expected of laboratory work. It is hoped that a scientific approach to the practical operation of steel pickling will not be unappreciated by the practical man who recognizes these anomalous occurrences.

Acknowledgement

The authors take great pleasure in recording their thanks to the Directors of The Staveley Iron and Chemical Co. Ltd., for permission to present this paper.

APPENDIX

Determination of Deposited Nickel

After dissolving the nickel deposit in *aqua regia* the liquid was boiled to drive off nitrous fumes. Ammonium chloride and ammonia were added and the solution boiled until the precipitated iron hydroxide was coagulated. The ferric hydroxide was then readily filtered off and washed with hot ammonium-chloride solution. The solution was then concentrated until the green colour of nickel was evident (about 75 ml.). From this point, two analytical procedures were used. Initially, the concentrated solution was made just acid with hydrochloric acid. 5 gm. sodium acetate, and 15 ml. glacial acetic acid were added and the

(Continued in page 452)

High-Productivity Barrel-Plating Line

(Continued from page 433)

Other Finishes and Future Plans

A small number of components is plated with silver, using an Efco PX.12 barrel. This is at the moment operating in an adjoining bay, but space has been provided for the introduction of a silver line into the main plating shop at some future time. Also situated in the plating shop is a small barrel used for the production of a phosphate coating for certain specialized applications.

For some applications, notably in the fabrication of hand chemical fire extinguishers, a rivet with a heavy tin coating is called for, and this is applied in a small hot-tinning unit situated in a shop adjacent to the plating line. Rivets are hot tinned by immersion in the tin pot in a perforated basket after fluxing in zinc chloride; excess tin is then removed in a centrifuge, after which the rivets are passed over a scattering device to prevent individual items adhering together before they enter a cold water quench.

Stove enamelling of rivets is carried out in a separate shop where rivets to be finished in black or a variety of colours are tumbled in a large barrel with a carefully determined amount of paint, after which they are stored in a convection oven on wire mesh trays. Two coats are applied,

resulting in a very hard, durable high gloss finish.

A small amount of work in light alloy is also anodized in chromic acid and dyed to DDT.327.

Chromium plating, which is carried out in an Efco automatic screw-feed barrel, slightly modified to meet the customers special requirements, is also carried out in a separate shop.

As mentioned earlier in this article, the new installation has resulted in considerable saving in labour costs and in increased rate of production, although it is not, even now, working at full capacity. Further expansion in the future has been envisaged and space is available for the installation of an additional line with its own monorail conveyor adjacent to the existing cyanide line. (See Fig. 3).

There is no doubt that the whole installation has been planned and specially designed to convert what is all too frequently a neglected ancillary process on which the expenditure of thought, time or money is begrudged, into a highly efficient production line. In this respect alone the whole plant is of notable significance.

We are indebted to the Electro-Chemical Engineering Co. Ltd. for considerable assistance in the preparation of this description and to the Directors of the Bifurcated and Tubular Rivet Co. Ltd. for permission to publish it and for much helpful comment.

Overseas Review

(Continued from page 434)

the baths was variable, molybdenum was employed as an internal standard.

Magnesium

Magnesium and its alloys are finding many applications in aeronautics and comprise, for example, over 75 per cent of the exterior surface of the Ryan Firebox jet drone missile⁽⁵⁾. Surface treatment of the Naval version involves alkali cleaning, rinse, hydrofluoric acid dip, rinse, boiling for 30 minutes in a mixture of sodium dichromate and calcium fluoride, rinsing, drying and the application of a special paint system utilizing a vinyl-alkyd resin primer. The National Bureau of Standards has also been investigating chromate treatments for magnesium alloys⁽⁶⁾ and has shown that a new low voltage alkali chromate treatment produces grey-green coatings, which although not as uniform as those from the HAE or acid chromate anodizing treatments have equal or superior salt spray corrosion resistance. It differs in (a) operating at a much lower voltage—usually 10-12 volts A.C. and (b) having a simple solution composition of either sodium or potas-

sium hydroxide and the corresponding chromate in water (see also METAL FINISHING JOURNAL, 1955, 1, (6), p. 250). Still 'in the air,' but having nothing to do with magnesium, Pratt and Whitney Aircraft Co.⁽⁷⁾ report that 0.0003 in. nickel + 0.0001 in. cadmium electrodeposits diffused at 630°F. for one hour will withstand 100 hours salt spray, even if the surfaces are heated for 23 hours at 700°F. and 1 hour at 1,000°F. before exposure.

Crystal Gazing

Talking of future uses for aluminium in American motor-car body design, Leo Swoboda⁽⁸⁾ says "aluminium bumpers and hub caps will probably be the next bright-finished aluminium items to appear." Gas plating⁽⁹⁾ is also once again being hailed as having a great commercial potential for the application of refractory and high purity metal coatings. Time will tell!!

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HOT-DIP ALUMINIZED STEEL

Its Preparation, Properties and Uses*

By M. L. HUGHES, Ph.D., M.Sc., F.R.I.C., F.I.M.†

Introduction

THE coating of steel with aluminium is not a new idea. A process for doing this was patented in 1893 only a few years after aluminium became commercially available. Since then many methods have been devised for applying the coating.

The Calorizing process, initially developed in the U.S.A. about 1914, is now well known and the product is used mainly for its resistance to heat. The coating is an alloy of iron and aluminium and is produced by a cementation method. It is similar to the Sherardizing process for zinc/iron alloy coatings, and both processes have the same limitation as to the size and type of article which can be treated.

The application of aluminium coatings by metal spraying has developed greatly in the last 15 years. The excellent corrosion resistance afforded by such coatings was shown by the results obtained with aluminium-sprayed hydrogen cylinders during the last war⁽¹⁾; a steel building at a Sheffield works sprayed with aluminium in March, 1938, was found to be in excellent condition in 1952, despite the unfavourable conditions⁽²⁾. Sprayed aluminium coatings, when annealed to convert the coating to Fe/Al alloy, also provide good resistance to heat and this process is used for making annealing covers and similar containers. An important feature of metal spraying is, of course, the mobility of the process.

Aluminium has also been applied to steel sheet by cold rolling the two metals together, a process developed chiefly in Germany. Heavy roll pressure is used and this, together with the local heating produced, causes the bonding of the two metals. The steel base is hardened in the rolling operation and it is not easy to anneal it sufficiently without affecting the coating.

Aluminium coatings may also be produced by vacuum evaporation and by electrodeposition from non-aqueous or fused electrolytes but these processes are not yet operated on an appreciable scale. This applies also to coating with aluminium from the chloride vapour, a process similar to chromizing.

The hot-dipping process is basically the simplest and cheapest method of applying metallic coatings, but it has lagged behind other methods in the case of aluminizing. It is clearly the best method for the continuous coating of strip and wire and many fabricated articles. Investigation of the properties of hot-dip aluminized steel both in this country and abroad has shown it to have valuable properties including excellent resistance to heat⁽²⁰⁾, resistance to flaking on deformation, and atmospheric corrosion resistance at least equivalent to galvanized steel and often better. Also several processes have been developed for continuous hot-dip coating of wire and strip which can operate economically. Thus, great interest has been aroused in this material, but there is as yet only one pilot plant working in this country and that is for wire aluminizing, whereas in the U.S.A. the production and application of aluminized steel, although still on a small scale, is developing rapidly.

The time is opportune for examining the possibilities of developing the use of hot-dip aluminized steel in this country. It is hoped that this paper, detailing the properties of the material and briefly reviewing methods of manufacture and fields of application, will encourage this development, which should not be allowed to lag any longer, since it can contribute so much to increase the usefulness of that already most useful material—steel.

The Manufacture of Hot-dip Aluminized Steel

(a) The Continuous Aluminizing of Strip and Wire

The first large commercial aluminizing plant was that of Armco Ltd., at Middletown, Ohio. Cold-reduced strip is passed through a Sendzimir unit as for continuous galvanizing, but using a bath of aluminium, suitably alloyed, instead of zinc. In this treatment the steel strip is heated in hydrogen to reduce the surface oxide film and under this atmosphere it is immersed in the aluminium bath. Silicon up to 6 per cent or 7 per cent is added to minimize alloy formation and improve the ability of the coating to withstand deformation without flaking. A little beryllium also assists in this way and the addition of cerium as mischmetal improves the lustre and general appearance. The bath may also contain some magnesium.

*Abstract of a paper presented to the Sheet and Strip Metal Users' Technical Association, London, October, 1955.

†B.I.S.R.A.

Very little information is published regarding the details of the process such as strip speed, bath temperature, bath container, and protective measures at the inlet and outlet ends.

The product, as judged from several sample sheets 6 ft. by 2 ft., and some smaller samples, is most attractive in appearance. Two types of coating are available and these differ in coating thickness and composition. The surface smoothness can be varied according to requirement. Strip is provided in widths up to 48 in. and in gauges 12 to 30.

Work done by B.I.S.R.A. at Swansea has shown that clean, cold-reduced strip may be hot-dip aluminized at moderate speeds by comparatively simple methods⁽³⁾. Two-inch wide strip, after continuous cleaning by ordinary pickling methods, was protected against oxidation on its way into the molten bath by a film of copper or glycerol. The glycerol coating burned slowly at the entry of the strip into the bath, while the copper coating dissolved in the bath. The use of fluxes or a protective atmosphere was avoided in this way. Wire and strip were coated by this method at speeds up to 20 ft. per minute. The same pretreatment can be used for dipping fabricated articles. For many purposes the heavy capital cost of the Sendzimir units used in "Armco Aluminizing" would thus appear not to be necessary.

A comparatively simple method of aluminizing wire has been adopted by the American Chain and Cable Co. ("Acco Aluminized" wire). The process as described very recently⁽⁴⁾ consists merely of a preheating operation to facilitate the removal of drawing lubricant, followed by pickling, rinsing, fluxing and then hot-dip aluminizing by immersion in a bath containing up to 2½ per cent silicon. The flux is a hot aqueous solution of titanium or zirconium fluoride or mixtures of these with sodium or potassium compounds, and the fluxed wire is dried on its way to the bath. The schematic layout of this plant shows a water quench for the coated wire after it has passed over an overhead roller. There is no reference to wiping methods which present a bigger problem than in wire galvanizing.

(b) *The Aluminizing of Fabricated Articles*

Two methods of hot-dip aluminizing fabricated articles, including sheet steel products, are well established. The earlier of these is the Mollerizing process, originally developed in Sweden and now in operation in America^(5, 6, 7). A feature of this process is that the molten aluminium floats on the surface of a molten salt bath which includes barium chloride to increase its density and cryolite to increase its fluxing power. The bath is heated electrically using submerged electrodes. The cleaned article to be coated is lowered through the

comparatively shallow layer of aluminium into the molten salt underneath. It remains there until sufficiently heated and fluxed and is then removed through the aluminium layer. While immersed the article is the cathode and the molten aluminium is the anode of a low-voltage d.c. circuit. It is claimed that evolution of chlorine at the anode cleanses the aluminium while the action of the steel cathode improves the adhesion of the coating. Alloy formation is said to be reduced due to the short time of contact with the molten aluminium on removal. (Metallographic examination of a Mollerized sample, of very good general appearance, showed an appreciable alloy thickness.)

This process is simple and has a number of advantages. A ceramic container is used, the fluxing and dipping operations are combined, iron-pick-up is reduced since the sample is not in contact with aluminium during its heating up period, and capital outlay should not be excessive.

A more recent process, which has some points in common with the Mollerizing process, is that developed by General Motors and now known as the "Aldip" process^(8, 9). The fluxing treatment in molten salt is carried out in a separate electric furnace, after which the article is transferred to the molten aluminium contained in an induction furnace. The salt bath has a layer of molten aluminium beneath it and is stirred. It is probable that this layer of aluminium acts as a scavenger, removing iron salts from the flux. Stirring of the bath would assist this action.

Resistance to Corrosion

Good resistance to atmospheric corrosion was shown by a large variety of hot-dip aluminized samples exposed by the American Society for Testing Materials⁽¹⁰⁾ at various American stations for a very long period. Aluminium coatings gave better results than zinc coatings which were of similar or greater thickness and, therefore, much heavier. Field tests with sprayed aluminium have also given very good results⁽¹¹⁾, but these coatings were much thicker than the hot-dip aluminized coatings containing silicon.

Manufacturers claim that Al coatings are much superior to zinc coatings, e.g., Armco claim six times the life for equal coating weight. This means about 2½ times the life for equal thickness. According to Westerman⁽⁴⁾, referring to "Acco" aluminized wire, "preliminary data indicate that aluminium coatings are substantially superior to equivalent thicknesses of zinc coatings exposed in industrial and highly humid atmospheres. Salt-spray corrosion data show less pronounced differences."

Aluminized steel prepared by B.I.S.R.A. has been given laboratory corrosion tests, is now

undergoing atmospheric exposure tests at two stations and has been given a few trials under severe conditions. The laboratory tests were intended to show whether or not aluminized steel had the good resistance to humid and sulphurous atmospheres usually attributed to it. Samples suspended over water which was alternately heated and cooled behaved much better than companion galvanized samples. Good results were also obtained in the CRL Humidity/SO₂ or "Beaker" test. During these tests, samples selected to show the effect of uncoated spots did not show the increased anodic attack which had originally been expected. A panel 6 in. by 3 in. having such uncoated areas was exposed to the atmosphere at Swansea, together with a similar panel of good galvanized sheet. After 3½ years the galvanized panel had lost 0.69 gm., equivalent to 0.08 oz. per sq. ft. of surface, which indicates a mild environment. The aluminized panel had gained 0.16 gm., largely due to rust formation at the bare spots which would mask any small change due to attack on the aluminium. An aluminized panel, also 6 in. by 3 in. and having two cut edges (6 in. and 3 in.) but with no uncoated spots, was later exposed with the others. After two years three months, this had gained the minute amount of 0.05 gm.

The samples were merely lightly brushed to remove loose dirt and dust and then swabbed with acetone before weighing. More extensive tests are being carried out by the Corrosion Section of B.I.S.R.A.

Since aluminized steel was expected to show up the best under conditions too severe for galvanized steel, samples were exposed in a ventilator of a railway tunnel, representing extremely severe conditions. The tests were carried out with and without painting, but in both cases the coating was seriously damaged after *three months* exposure. This work was carried out by the British Railways Research Department and they have suggested that the poor results were caused by chlorides derived from the fuel ash, which would break down the protective oxide film.

Better results were obtained in two other field tests, both under severe conditions. In one of these tests, two panels 12 in. by 6.5 in. by 0.085 in. were inserted in the sheet-steel flue of a grass drier. The panels were installed for 109 days. The flue gases were not analysed but analysis of a sample of rust from the inside of the flue showed the presence of a high proportion of sulphur (15 per cent as SO₃). On removal and after cleaning with a bristle brush and swabbing with benzene, specimen A, at the lower position, had a grey surface showing no signs of breakdown, attack being limited to uniformly distributed pinpoints amounting to perhaps 1 per cent of the area. The condition of

panel E was even better.

The weights before exposure and after cleaning showed that Panel A gained 1.4 gm. and Panel E 0.4 gm. These changes are very small compared with the deterioration of steel sheets with a variety of finishes previously tried.

A panel with 4 to 5 mils coating of Al was exposed in the false base of a purifying tower at a gas works, where severe corrosion can occur. When removed after 136 days the specimen had a bluish deposit and also brown stains which could be readily brushed away to reveal bright aluminium. This also was considered a very satisfactory performance for the time of exposure.

Hot-dip Aluminizing of Other Metals and Alloys

Although aluminizing confers, as stated, good scaling resistance to mild steel up to 800° C., this fact can only be utilized up to, say, 550° C. if the steel is subjected to much stress.

For some engineering purposes, such as high-pressure steam generation, creep-resisting steels are necessary. The scaling of such steels sets a limit to their use and hot-dip aluminizing (or other methods of protection) may help to solve this problem. It is necessary to show that neither the dipping operation nor the presence of the coating will affect the properties of the steel during use. A number of creep and fatigue specimens in suitable sheet steels (e.g., ½ per cent Mo) have been hot-dip aluminized by B.I.S.R.A. for testing elsewhere. This type of steel is quite readily aluminized and the rate of scaling at 800° C. is greatly reduced.

An interesting example of the value of an aluminized coating on a turbine casing used in a steam power plant operating at 610° C. is given by Buchholtz, Ruttman and Schinn⁽¹²⁾. After heating in air for 14,470 hours at 600° C., the aluminized zone was relatively unattacked, whereas an adjacent unprotected surface had scaled heavily.

Other materials which have been successfully hot-dip aluminized include stainless steel, referred to later, Cr/Ni alloys for resistance to sulphur, molybdenum owing to the volatile nature of its oxide, titanium to facilitate its working and to prevent the absorption of gases, and cast iron to reduce oxidation and growth. Results quoted by Whitfield and Sneshunoff⁽¹³⁾ show are remarkable drop in the attack on 18/8Cr-Ni steel in a sulphurous atmosphere at 732° C. A loss of weight of 17 per cent after 24 hours was converted to a gain of 0.1 per cent after 192 hours. Even at 927° C., there was little attack after 48 hours. Other equally remarkable results are quoted. Unfortunately, too little information is given concerning these tests. The same authors quote the results obtained by G. Kremer and K. E.

Volk⁽¹⁴⁾ on heating various Cr/Si steels, 18/8 Cr-Ni steel, plain steel, and aluminized plain steel for 50 hours, in a current of H_2S . A very marked decrease in the rate of attack was found at 498° C., 598° C. and 697° C.

For certain purposes hot-dip aluminized mild steel, or low-alloy steel, is replacing the more expensive heat-resisting steels in American engineering practice. Diesel-engine exhaust manifolds in stainless steel (18 Cr, 10 Ni) have been satisfactorily replaced in this way using Aldip processed steel with a saving of 2½ lb. of nickel and 4½ lb. of Cr for each manifold. Similarly, stainless steel has been replaced in military tank heat exchangers for use at 900° F. (482° C.)⁽⁹⁾.

For maximum heat resistance the thickest possible coating would appear to be advisable. If such a coating includes a thick outer layer, trouble with spalling may be encountered. A preliminary heat treatment may then be necessary when the outer layer is rapidly transformed to alloy. This diffusion process makes the change in composition and properties through the coating thickness more gradual and so reduces the danger of spalling. The maximum thickness is partly decided by the necessity to avoid excessive immersion times when coating.

Sundry Properties and Applications of Hot-dip Aluminized Steel

The silicon-alloyed coatings have the useful property of retaining their lustre at the lower temperatures, and their reflectivity may be useful (a) to keep heat out, as with storage vessels for low-boiling-point liquids, and (b) to keep heat in, as in the lining of ovens. When the coating is converted by heat treatment into the dark alloy of Fe and Al, the surface has a high emissivity and this has been applied in the manufacture of vacuum-tube parts in Europe and in America. (The original aluminium coating may be applied by rolling and then annealed at 650° C.) The thermal emissivity is said to be 80 to 85 per cent⁽¹⁵⁾.

An attractive property is that the surface can be anodized and then dyed in attractive colours as is done with sheet aluminium. Work done by B.I.S.R.A. at Swansea shows that a coating having a fairly thick outer layer and a smooth surface is necessary for the best results.

If decorating by painting is desired, the hot-dip aluminized surface is much more suitable than newly hot-galvanized surfaces.

The hardness of the iron-aluminium alloy suggests that the coating should have appreciable resistance to abrasion, but no test results are available to confirm this.

Since the heat resistance is provided by the iron/Al alloy it is worth noting the properties of the Al/Fe alloys synthesized by Sykes and

Bampfylde⁽¹⁶⁾. Alloys within the range 9 to 16 per cent Al showed remarkable heat resistance. During the discussion of this paper it was stated that a small tray of 12 per cent Al/Fe alloy in a heat-treating furnace showed no signs of scaling after 4 weeks at 1,050 to 1,110° C., including one hour at 1,250° C. "It showed some signs of sagging in the middle!" The fact that such alloys have not been commercially utilized was no doubt due to their hardness and the difficulties of shaping. It has now been found possible to produce quite ductile strip from the 16 per cent Al alloy by special methods of rolling⁽¹⁷⁾.

The welding properties of the aluminium-coated sheet are important to those interested in the possibility of fabricating structures from sheet. The Armco catalogue states that "excellent welds are secured when spot-welding sheets exactly as they come from the mill with no surface preparation." Generally, of course, some form of cleaning is needed. Details are given of other welding techniques. The spot-welding of hot-dip aluminized steel has been examined by Rosenblatt⁽¹⁸⁾ and by Brown⁽¹⁹⁾. The latter gives detailed results for welds made under various conditions. His conclusions are favourable and the consistency of the results is remarked upon ("The dispersion of shear strengths of welds made in this material is very low"). If the final product is intended to withstand much heat it may be necessary to protect any exposed cut edges if growth of oxide there is undesirable.

Conclusion

The properties of aluminized steel outlined here indicate the fields in which the material should find the greatest applications. Its uses are already very numerous and the scale on which hot-dip aluminizing is being carried out appears to be rapidly expanding in the U.S.A., but not in this country. The competition which the steel-sheet industry has to meet from aluminium sheet may lead to the use of hot-dip aluminized sheet instead of galvanized steel when the conditions are unfavourable to the latter. The fact that aluminium coated sheet is easier to decorate and may be made very attractive by anodizing and dyeing may encourage its use in preference to galvanized steel.

It is, however, its heat resistance which gives most scope for its wider use. Hot-dip aluminized sheet could be used for the fabrication of low-temperature recuperator tubes, steel flues and chimneys and for the less critical parts of gas turbines. The use of aluminized steel for the exhaust systems of cars and trucks is well established. One large American motor organization is said to be operating 54 dipping units for this purpose alone. Aluminized wire mesh has already

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THE CHEMICAL RESEARCH LABORATORY

Some Details of work in Progress

WORK now being carried out at The Chemical Research Laboratory, Teddington, Middlesex, is divided into six main groups—corrosion of metals, the inorganic and organic sections, microbiology, high polymers and radiochemistry. These are supported by a general services department, i.e. engineering workshops, a glassworking section, library and stores. The laboratory is one of the stations of the Department of Scientific and Industrial Research and was founded in 1925. The present main building was completed in 1933. To this was added the Hales Building in 1947, and the radiochemistry and microbiology buildings in 1952. A total staff of approximately 200 includes 45 scientific officers, 75 experimental officers and 30 scientific assistants.

All the work being carried out is not directly in the field of this Journal, but some brief details of some of the work is given below.

Corrosion Studies

Radioactive Tracer Studies of Corrosion Inhibitors.—The mode of action of chromates in inhibiting corrosion of steel in aqueous solution is being investigated by many workers. Research at Teddington has been based on the use of potassium chromate containing a proportion of radioactive chromium atoms. The amount of chromium found on a steel surface after immersion in such a radio-active solution is estimated from the amount of radiation emitted from the surface. Using this technique, it has been shown that during immersion in chromate a protective film containing

chromic oxide grows on the surface of the metal, in the same way as a surface film of ferric oxide grows during exposure of the steel to air.

Immersed Corrosion at Elevated Temperatures.—The influence of temperature on the corrosion rate of metals in contact with aqueous solutions has received only slight attention in fundamental corrosion studies. The need for more detailed information has been emphasized by the increasing number of enquiries received by the corrosion of metals group on metallic corrosion in such equipment as hot-water storage tanks, churn-washing machines, domestic hot-water systems, cooling systems, and boilers. Work has been started by investigating the corrosion of mild steel in boiling solutions containing various types of salts, normally present in natural waters, at different concentrations. The object of this work is to assess the relative corrosivity of these salts and thus to furnish information of value in assessing the corrosivity of natural waters.

Boiler tube corrosion is also being studied as a long-term project. A series of experimental model boilers are used in an endeavour to solve the problem of failures of marine and industrial boiler tubes. This research has already been in progress a number of years. The inhibition of microbiological corrosion in underground situations has also been a long-term project. Testing of steels in flue-gas atmospheres is another investigation which should eventually benefit the iron and steel industry.

Stoving by Convection and Radiation

(continued from page 424)

Too quick driving out of solvents, followed by immediate stoving would cause bubbling or blistering of the coating film. Generally speaking, drying time in conveyor ovens of the hunch-backed type is longer than in radiant-heating ovens, but it is not the actual drying period which influences efficiency. Drying time of continuous convection stoves is less important as the oven length increases. What is required by the users is that the rate of flow of goods obtainable should be suitable for most production schedules. It is claimed by makers of modern conveyor ovens using forced convection that as the risk of "shadowing" is negligible, loading can be increased as much as the shape and weight of the articles permits, so that ultimately the rate of delivery of stoved goods may be comparable with those obtainable from a conveyor type radiant stove of much greater length and demand for floor space. A typical example is treatment of

flat steel sheets. A radiant stove may take only single sheets at a time at say 3 times the rate (i.e. 1/3 the convection stoving time). A convection conveyor oven could, however, be loaded with 3 to 5 sheets, and although the time might take 3 to 5 times longer to complete stoving, output would still be equal.

The above will indicate that both methods have their place.

(to be concluded)

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SILICONES

A PAPER on "Silicones" was presented to the National Conference of the Purchasing Officers' Association by A. K. Simcox, B.Sc., Home Sales Manager of Midland Silicones Ltd. In the paper Mr. Simcox describes the nature and uses of silicones as fluids, emulsions, greases, resins, varnishes and rubbers. Heat resistance is still the most remarkable and useful property of all silicones. Silicones are resistant also to the effects of sunlight and ozone. A third general property is resistance to water. Finally, as a class they have excellent electrical insulating properties.

The price of silicones is high but they are used because their special properties have enabled some product to be markedly improved in performance or durability at a cost that is fully justified.

Hot-dip Aluminized Steel

(Continued from page 450)

been successfully used for conveying systems as in glass annealing. Reference has already been made to the dipping of fabricated articles such as small heat exchanger units. This field is wide, varying from steel castings for furnace building to the hot-dip aluminizing of the heads of exhaust valves. Batches of valves, held in a suitable jig, are dipped simultaneously by one American firm.

These facts lead one to conclude that, in America at least, aluminized steel is now accepted as having its own special properties and uses. This seems to be true also of the Scandinavian countries, but not so far of Britain.

Acknowledgments

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GERMANIUM RECTIFIERS

Some Notes on U.S. Developments

THE germanium power rectifier is a comparatively new development and has aroused great interest both in this country where it is already under development and in the U.S.A.

Details have just been released by the General Electric Co., U.S.A., of the germanium rectifier equipment manufactured by the company for use on anodizing and electroplating lines. Of the advantages claimed for germanium rectifiers the main ones are: operation is at over 90 per cent efficiency even at 12 volts d.c. and at only 25 per cent of the rated capacity; maintenance costs are very low, due to the minimum number of moving parts; installation costs are low; voltage regulation is within about 9 per cent from no load to full load; and the equipment has a high power factor and power costs are lower.

Acid Pickling of Mild Steel

(Continued from page 445)

whole diluted to 150 ml. with water. This solution was heated to 70°C. and 25 mls. of 2 per cent alcoholic solution of "oxine" added. The solution was boiled until the precipitate had coagulated, after which it was filtered off. The precipitate was washed with boiling water and then dissolved in 1 : 1 hot hydrochloric acid in a stoppered bottle. Twenty-five millilitres of N/10 potassium bromate and 20 ml. of 10 per cent potassium bromide were added and the solution left to stand in the dark for five minutes. One gram potassium iodide was then added and the liberated iodine was titrated with sodium thiosulphate with starch as indicator. This procedure is rather tedious and a quicker but no less accurate method was developed.

This method* involved adding excess disodium ethylenediamine tetra-acetate solution (4 gm. per litre) to the concentrated solution which was just acid. This solution was buffered to pH 10 with 6.75 gms. ammonium chloride in 57 ml. of 0.880 ammonia made up to 100 ml. with water. One or two drops of indicator ($\frac{1}{2}$ gm. Eriochrome Black T in 30 ml. isopropanol made up to 100 ml. with water) were added to give a blue colour. This was titrated with analytical-quality magnesium sulphate heptahydrate (2 gm. per litre) until a purple-pink colour was reached. The reagents were standardized against a known nickel concentration.

The nickel weight determined in either case was divided by 106 to give the weight of nickel deposited in mg. per sq. cm. of panel area.

*Pribil, R.: "The Chemical Age" January 8, 1955, pp. 141-5.

FINISHING

NEWS REVIEW

NEW FACTORY FOR FESCOL LTD.

Official Opening of Springbank Works, Huddersfield

A NEW factory, built specially for Fescol Ltd., North Road, London, N.7, for the electrodeposition of metals was formally opened by the Mayor of Huddersfield at Leeds Road, Huddersfield, on Tuesday, September 13.

The new factory, which has a floor area of about 14,000 sq. ft., is approximately twice the area size of the company's previous Huddersfield works at Cable Street.



General view of Springbank Works.

General view of interior of new Fescol works.



Most of the plant at the new works has been transferred from the previous factory, but the greater availability of space has allowed a far more efficient layout and the inclusion of modern electric hoists and other handling aids.

Known as Springbank Works, the factory has a two-storey frontage containing offices, laboratory, canteen, etc., and the main works, covering an area of 10,000 sq. ft., which is at the rear, includes a chromium-deposition shop, nickel-deposition shop, stores and inspection departments.

The six vats for chromium deposition are all installed in special pits to give them a common working height. Hoists are provided over the vats and shafts up to 8 ft. in length can be treated by the Fescol process. Each vat is powered by a separate "Westalite" rectifier set, and adequate fume extraction and ventilating plant is provided. An interesting feature is that cool air entering the building has first to pass the transformers and rectifiers adjacent to the vats and so cools them.

Five of the rectifier sets have an output of 1,500 amp. at 12 volts and one an output of 1,000 amp. also at 12 volts. Each rectifier set is a self-contained unit, with mains and auto transformers and control gear.

The layout of the nickel-deposition shop is similar to that of the chromium shop, but power is obtained from motor-generator sets having a total output of 3,000 amp. at 10 volts. In case of power failure, accumulators with a capacity of 4,000 amp. at a 10-hour rate of discharge have been installed.

Throughout the works ducts are provided in the concrete floor to accommodate the gas, water, compressed-air and electricity supplies to the deposition vats. Except for the offices the building is painted throughout with chlorinated rubber paint.

Provision has also been made in the works for the special plant required for the direct deposition of chromium on aluminium, a process developed by the company.



INSTITUTE OF METAL FINISHING

Autumn Meeting

THE Fourth Annual General Meeting of the Institute of Metal Finishing will be held in the Thames Room of the Charing Cross Hotel, London, W.C.2, on Monday, November 14, at 11 a.m.

Following the meeting at 1 p.m., there will be an official Luncheon at the Hotel.

At 3 p.m. the new president, Mr. R. A. F. Hammond, B.Sc., A.R.C.S., F.R.I.C., will be inducted into office by the retiring president, Professor J. W. Cuthbertson, D.Sc., F.I.M., A.M.I.E.E. Mr. Hammond will then deliver his presidential address under the title of "Research and Industrial Application in Metal Finishing."

CHANGE OF ADDRESS

Borax and Chemicals Ltd., Kingsbourne House, 229, High Holborn, London, W.C.1, have announced that the new address of the company's Birmingham office is now: 15, Carrs Lane, Birmingham 4. (Tel.: Midland 1159).

ULTRASONIC TESTING OF GALVANIZING TANKS



THE illustration above shows an interesting use of the Supersonic Flaw Detector manufactured by Kelvin and Hughes Ltd., at the Crittall Manufacturing Co. Ltd., where large numbers of hot-dip galvanized metal window frames are produced.

The spelter baths are approximately 5ft. x 10 ft. and 9 ft. deep, built of 2-in. mild-steel plate with a brick flue surround. The furnace is oil fired. Over a period the hot spelter affects the bath plate. Consequently the liquid is pumped out of one bath into another and the empty bath is examined with particular regard to the thickness of the bath plate. The use of the Kelvin Hughes MK V S.F.D. reduces the measuring procedure to about a day or a day and a half.

At regular intervals the bath is taken out of service, emptied and cooled. The lining is marked off by vertical chalk marks into sections. The engineer then takes the Flaw Detector into the tank and tests the thickness of the bath plate at various points within the marked out sections. The results are entered on a chart and compared with previous figures.

Sectors showing reduced thickness are given closer examination with the Flaw Detector and thin places are welded up to the required thickness.



CELLULOSE DIPPING

What is believed to be the only firm in Britain operating a separate out-work cellulose dipping service department for such articles as broom heads, brush handles, wooden handles for kitchen utensils and similar articles made either of wood or metal which can be dipped in bulk and coated in one or more colours, is M. E. Beswick Ltd. The company, who operate a specialised stove enamelling service to industry through the medium of two modern and specially constructed and equipped factories at Ormside Street, London, S.E.15 and Oyster Lane, Byfleet, Surrey, have also recently opened this up-to-date bulk production cellulose dipping shop. The bulk dipping shop is operating at the company's Byfleet factory, but the demand for this type of service is so great that a similar department is to be opened at the Ormside Street works. The articles to be processed are hung on racks and let down into a tank of cellulose paint, raised, allowed to drip, passed through a special drying room, returned if necessary for an additional colour (repeating the same operation) and when dry present a perfectly cellulose-coated article. Over 400 articles per day are at present being treated in this way. In addition to their bulk dipping shop M. E. Beswick Ltd. operate departments for bulk stove enamelling, general jobbing work, metal pre-treatments, transfer and silk screening. They also maintain a daily collection and delivery service within a radius of 30 miles of each factory.

U.S. Firm Claims Success in Operating Improved Bright Nickel Plating Process

CONSIDERABLE economic and production advantages have been claimed by the S. E. and M. Vernon Co. of Elizabeth, New Jersey, U.S.A. as a result of adopting bright nickel plating in the finishing line for binder rings for looseleaf folders.

The company, one of the largest in the U.S.A. manufacturing this type of product, has found that the bright-plated ring has considerable sales appeal and that the adoption of the Nickel-Lume solution, recently developed by Hanson-Van Winkle-Munning Co., Matawan, N.J. has markedly reduced finishing times and costs. Savings of 20 per cent in time, 50 per cent in current and 25 per cent in nickel are claimed, as well as reductions in purification and maintenance costs arising from the higher stability and low operating temperature of the solution. Equipment suitable for a Watts nickel bath is all that is required. Ordinary auxiliary equipment may be used, filtration may be either periodic or continuous, ventilation is not required and heat demands are up to 25 per cent lower.

The process claims to produce smooth, bright nickel deposits which give good corrosion protection, have excellent colour and require no activation treatment in the process cycle between the nickel and chromium plating operation. It also exhibits good levelling properties with the result that some polishing and buffing operations on the base metal may be eliminated. The bath can be completely controlled by chemical analysis.

The claims for the process may be summarized as follows:—

1. Fully bright deposits with a pleasing white colour.
2. Good levelling properties.
3. Wide temperature operating range with no loss of brightness.
4. Good corrosion resistance.
5. Wide current-density operating range.
6. Ductile deposits with low compressive or tensile internal stress.
7. Good tolerance to impurities.
8. No activation of the nickel required prior to chromium plating or other deposits.
9. Complete analytical control of all constituents.
10. Stability over long periods of operation.

Continuous filtration of the solution is not required but continuous or periodic filtration through filter-aid materials may be necessary to remove solid particles and prevent excessive roughness. Batch purification is

usually unnecessary but if organic or inorganic types of contamination reach abnormally high levels, such a treatment may be employed effectively without any harmful effect to the bath. This nickel solution can be operated at unusually high speeds. Current densities up to 70 amp. per sq. ft. at elevated temperatures are readily obtainable. On the other hand, bright deposits are also obtained at room temperature with lower current densities.

The process is applicable to the plating of steel stampings, forgings and die castings, as well as brass, copper and aluminium parts.

In the illustration looseleaf binder rings are shown at the Vernon works



after coming out of the nickel-plating bath on the far left. The H-VW-M fully-automatic elevator-type conveyor is pictured during a transfer cycle with racks in the up-position, prior to lowering the work into the rinse tanks. Racks on the far right are shown going through a dryer during which operation the carrier arms remain in the up-position.

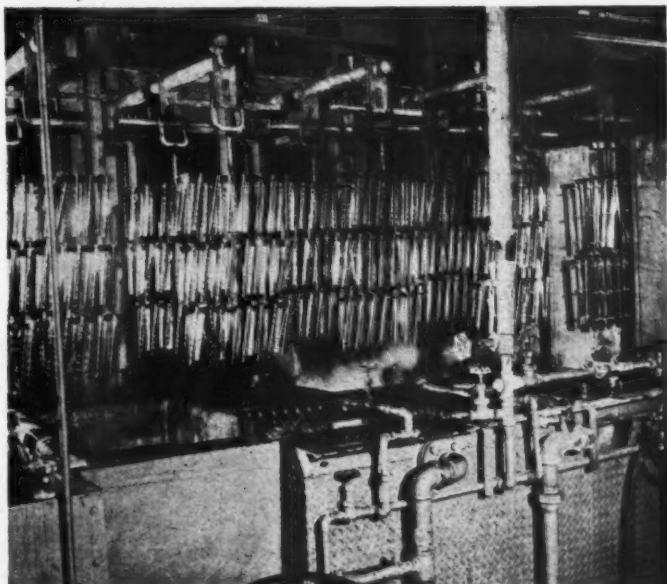
The recommended basic composition for the solution is as follows:

	Optimum	Limits	Make-up per 100 Gallons
Nickel sulphate	40 oz. per gal.	36-42 oz. per gal.	250 lbs.
Nickel chloride	6 " " "	4-8 " " "	37.5 "
Boric acid	5 " " "	4-6 " " "	31.2 "

To this solution are added three proprietary, patented brightening and anti-pitting agents.

Principal operating conditions of the process are as follows:

Temperature	75—140°F (120°F normal)
Current density	5—70 amp. per sq. ft. (30—40 amp. per sq. ft. normal)
pH	3.5—4.0 electrometric
Agitation	Conveyor motion or cathode rocker
Anodes	Cast Carbon or rolled depolarized





TECHNICAL AND INDUSTRIAL APPOINTMENTS

Mr. Jack C. H. Stearns has been appointed executive vice-president of Dow Chemical Inter-American Ltd.



MR. JACK C. H. STEARNS

A member of the export board of directors, Mr. Stearns joined the company in 1937 handling general sales of magnesium in the mid-western part of the U.S.A. In 1944, he became manager of ingot sales and in 1954 he was appointed to an executive position with the export companies. Mr. Stearns studied chemistry and chemical engineering at Johns Hopkins University and George Washington University.

OBITUARY

Scott: Mr. C. A. Scott who was for many years chief erection engineer of EFCO Ltd., Weybridge, died suddenly on Saturday, September 17.

Cruse: Mr. H. A. Cruse, a director of the Westinghouse Brake and Signal Co. Ltd., died recently. Mr. Cruse retired from his executive post as general works manager in December of 1954 after 53 years' service with the company.

TRADE and TECHNICAL PUBLICATIONS

Aluminum-coated Steel Wire: Reference to aluminium-coated steel wire produced by the patented Lund.n process is given in an article in the August 1955 issue of "Aluminium News" published by Aluminium Ltd. The chief uses of the wire are expected to be in the utilities and communications fields. While not intended as a prime electrical conductor, aluminium-coated wire is more conductive than galvanized types, and affords excellent protection, particularly in humid atmospheres.

"Jenolite News": Vol. 7. No. 9 of this publication from Jenolite Ltd., 13-17, Rathbone Street, London, W.1, describes the use of the company's products in servicing "Stacatrac" fork-left trucks at the West London service depot of I.T.D. Ltd. The trucks are completely dismantled during servicing and parts are treated with Jenolite RRN. Another article deals with the use of Jenolite in the production of outdoor advertising signs.

"The Nickel Bulletin": Volume 28, Nos. 6-7, of this publication from The Mond Nickel Co. Ltd., Thames House, Millbank, London, S.W.1, contains brief abstracts of the papers presented at the recent Institute of Metal Finishing Conference. Other abstracts are included of papers and articles on such subjects as the influence of physical condition and the processing of the basis metal in electroplating, structure and properties of electrodeposited coatings, electrodeposition of nickel with perfluorinated acids, electroplating on magnesium, properties and uses of electrodeposited nickel, specification for heavy nickel plating, thickness testing of electrodeposited coatings, and polarographic analysis of nickel plating solutions.

Epoxy Resins: Bulletin No. 151 in the series of Research Notes published by Aero Research Ltd., Duxford, Cambridge, is entitled "Araldite Epoxy Resins: Some Details of the

Various Forms Now Available and of Their Uses". The bulletin gives brief details of the range of uses covered by the various forms of resins now available and gives many illustrations of typical applications.

"Kanigen Chemical Nickel Plate": The Kanigen plating process which depends on the catalytic reduction of a nickel salt by a hypophosphite, is fully described and illustrated in a booklet issued by Albright and Wilson Ltd., 49, Park Lane, London, W.1. The process provides a hard, uniform, non-ferrous coating on components of any shape, and the coating is a nickel-phosphorous alloy (8.5 per cent P.) which possesses many valuable properties. The main advantages of the process are: perfect coverage and plate uniformity (the solution has 100 per cent throwing power), as no electrical contact is required for the process many articles may be plated by simple immersion in baskets, most metals, including aluminium and plastics, ceramics and glass can be plated, and the composition and structure of the plate is such that its physical properties are in many respects superior to those of electroplated nickel, particularly from the point of view of corrosion resistance and high hardness. The thickness of the plate can easily be controlled to within ± 10 per cent of the average, irrespective of the complexity of the part being plated. The appearance of the plate depends largely on the finish given to the basis metal, since it accurately reproduces the contours of surfaces to which it is applied. A bright surface with high reflectivity can be obtained if the basis metal is polished before plating. The normal hardness of the plate is 500 D.P.N. but this can be increased to 1000 D.P.N. by suitable heat treatment. Kanigen plate is completely amorphous and thus has a low porosity. Full details of corrosion studies are also given in this booklet which may be obtained from the company at the above address.

NEWS IN BRIEF

B. O. Morris Ltd., Coventry, has concluded an agreement with **Hammond Machinery Builders**, of the U.S., to manufacture its automatic and semi-automatic polishing equipment, including rotary and straight line machines, under licence in this country. Production of the range has already commenced.

Over £500,000 is to be spent by **Monsanto Chemicals, Ltd.** on the construction of a new plant to manufacture phthalic anhydride at its

Newport (Mon.) factory, which is expected to be in operation towards the end of 1957. The additional capacity is being built to meet increased demand from the main users, the paint, plastics, and allied industries.

A journal, designed to keep exhibitors in touch with preparations for the British Industries Fair, is to be launched next month. The "BIF Bulletin" will be sent free to 12,000 past, present, and potential exhibitors at both the London and Birmingham sections.

NORTON GRINDING WHEEL CO. LTD.

Announce Large ex- pansion Programme

CELEBRATING their 25th Anniversary this year the Norton Grinding Wheel Co. Ltd., have announced a £500,000 expansion programme over the next three years. The programme will provide more factory space resulting in greater efficiency and giving facilities for the manufacture of an even wider range of products, including refractory products for atomic-energy work. The wide range of grinding wheels already produced by the company can be gauged from the two examples shown in the illustration, which includes the smallest wheel ($\frac{1}{4}$ in. dia.) and the largest wheel (72 in. dia.).

The announcement of the expansion programme was made by Mr. Milton P. Higgins, president of the parent company, Worcester, Mass., U.S.A. at a Service Award dinner; Mr.

Higgins is visiting this country with another of the directors of the American Company, Mr. A. Donald Kelso, who is also president of Norton Behr-Manning Overseas Inc.



METAL FINISHING ASSOCIATION DISCUSS OUTWORK PLATING

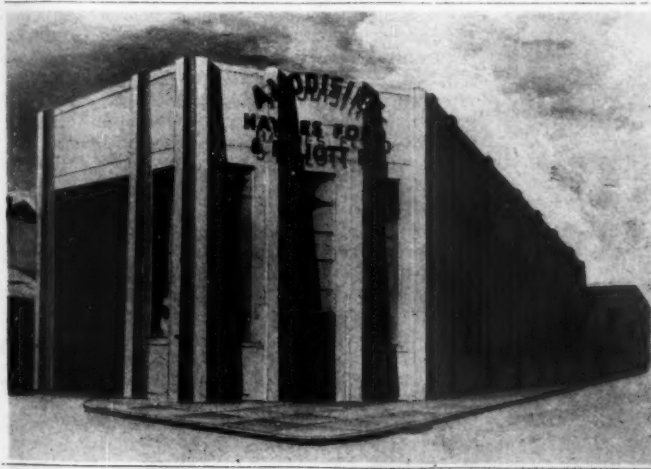
THE Birmingham Area Committee of the Metal Finishing Association has discussed the problem which faces outwork plating firms in identifying manufacturers' specifications for finishing. The Association states that orders for finishing are often placed with the outwork plater by sub-contractors or by manufacturers of component parts who quote the specification of the principal manufacturer without even knowing to what the specification refers, far less the details.

It is a matter of inconvenience and delay if the outwork plater has to obtain these particulars by going back along the chain through which the order has come, and, as an additional service to members the Association is to set up a library of manufacturers' finishing specifications including those of Government Departments and the B.S.I.

In order to achieve this object, the Association states that it would be glad to receive from any manufacturer a copy of any plating specification of their own.

A NEW extension has been made (see left) to the Pritchett Street Works, Birmingham, 6, of Haynes, Ford and Elliot Ltd. Erected by Beechams Buildings Ltd., Shipston-on-Stour, the extension has been specially designed for the anodizing processes for which it is used.

All forms of pre-treatment of aluminium, including polishing, etching, and brightening, are carried out in this building, and the Bengough Stuart chromic-acid plant and dye department have both been enlarged. The modern polishing plant has a specially trained squad of polishers who are dispatched all over the country to carry out "on site" work. Although principally devoted to anodizing, the new building also carries extensive nickel, chrome and cadmium plating plant.



THE illustration on the right shows a session of a technical conference organized by the Electro-Chemical Engineering Co. Ltd., at Weybridge, which was attended by twenty-two of the company's Efco-Udylite distributors. Lasting for three days the conference had representatives from France, Germany, Holland, Belgium, Switzerland, Spain, Italy, Norway, Sweden and Denmark. Dr. R. Saltonstall, technical director of the Udylite Corp., Detroit, was also present, and is seen in the illustration presenting a paper to the conference.



Latest Developments in PLANT, PROCESSES and EQUIPMENT

Two-phase Metal Cleaning

MASS-PRODUCTION metal cleaning is of great importance in many industries where the removal of polishing and buffing compounds, swarf, shop dirt, lubricating oils, etc. from metal surfaces is an essential prerequisite to enamelling, electroplating, phosphating, painting or inspection.

Previously, metal-cleaning methods depending on the action of trichlorethylene and similar solvents in liquid or vapour form have had the disadvantage that certain types of soil which were water-soluble were not removed—e.g. brazing residues and the inorganic salts deposited by finger prints. Furthermore, metal objects which were recessed or of complex internal shape could not be adequately cleaned by the per-

colating vapour of the solvents commonly employed.

The Di-Phase processes originally introduced in the United States were designed to overcome some of these difficulties, since they employed two different and immiscible liquid cleaners which made contact with the work virtually simultaneously, either by dipping or spraying. These cleaners are becoming widely used in the automobile, engineering and appliance industries, and have the advantages of being non-toxic, rust-inhibiting, and together capable of removing every type of soil from the metal surfaces to be cleaned. They also offer notable operating economies over trichlorethylene, and being used in concentrations of only 3 to 5 per cent require no elaborate recovery process. They are equally suitable for ferrous and non-ferrous metals, including zinc, aluminium and magnesium.

A great improvement in the method of application of the di-phase cleaners has recently become possible by the development of the range of Efco Agidip machines which are specially applicable to the batch cleaning treatment of small intricate components. (Fig. 1.)

These machines are pneumatically operated, using the normal factory air line as a source of compressed air at 80 lb. per sq. in. No elaborate installation is required, and the machines are portable. Heat is provided by two thermostatically controlled 3-kW immersion heaters fitted in the base of the tank, which is lagged to reduce heat losses.

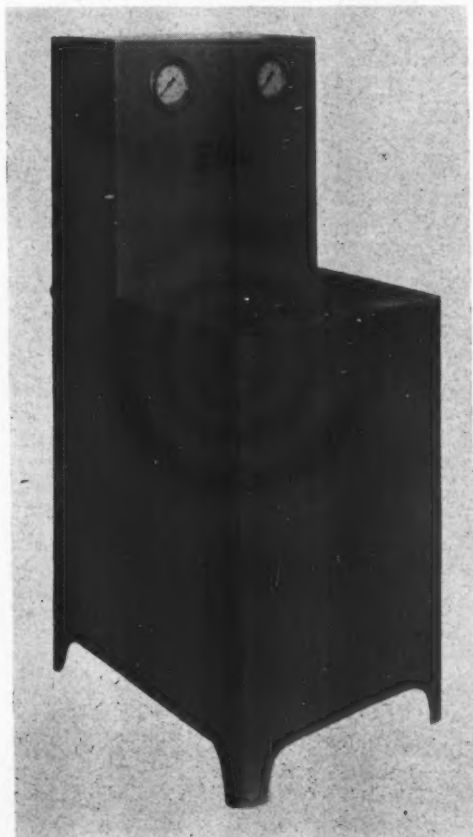
The Agidip action consists in a regular and rapid up-and-down movement of the work container through the two layers of the di-phase solutions, causing the items in the easily removable work container to receive a thorough and penetrating dip in each phase in turn on each upward and downward movement. This action results in a thorough cleansing of both oil and water-soluble soils from the metal surfaces of the work.

The machines are of two sizes, of capacity either 20 lb. or 65 lb. per load. The cleaning cycle takes approximately two minutes, so that the potential hourly output is 5 cwt. or 16 cwt. respectively. The larger machine can conveniently handle such items as cylinder blocks and therefore should be of particular interest to the automobile and garage industries.

After cleaning in the Agidip the work may be dried at once by an air blow-off, or better, passed in a drying cycle through the Agidrier machine in which a current of hot air is fanned through the work as it moves up and down in an action similar to that of the Agidip.

The whole range of machines is available from the Electro-Chemical Engineering Co. Ltd., Queens Road, Weybridge, Surrey.

Fig. 1.—Two-phase metal cleaning equipment.



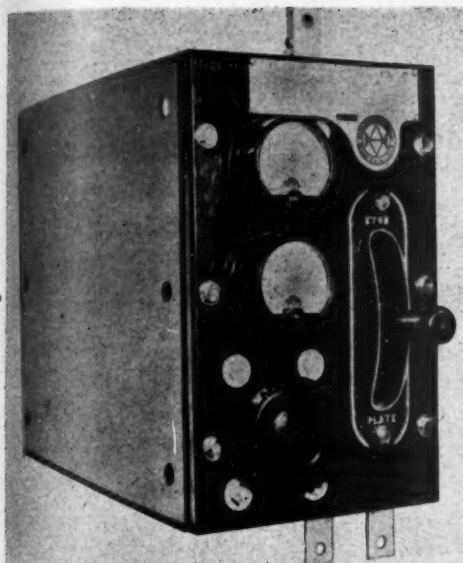


Fig. 2.—Carbon-pile tank rheostat.

Carbon-Pile Tank Rheostat

THE Hanson-Van Winkle-Munning Co., N.J., U.S.A., have announced a carbon-pile tank rheostat for electroplating that is particularly useful when precise current control is required. The new Universal Tank Rheostat consists of a rectangular carbon-plate rheostat, an adjustable nickel-chromium resistor, a reversing switch, a voltmeter and an ammeter. (Fig. 2).

Beside providing control of the plating current, the new rheostat permits the selection of the proper tank rheostat without specifying "voltage drop." Ordinarily this is not possible with standard knife- or rotary-type rheostats. The new unit provides all tank voltages for a specified line voltage up to 12 volts, and amperages ranging from 30 to 250.

The flexibility and range is possible because of the adjustable resistor located at the top of the heavy steel case which houses the components of the unit. This feature permits basic adjustments to be made on the unit after installation. Fine current adjustments are made by the carbon-pile component.

Since carbon-pile rheostats provide stepless control of electrical current, they are particularly applicable where fine current adjustments are desired. Since the basic adjustments are made with the resistor, the carbon pile operates in the range of its maximum effectiveness.

The reversing switch on the Universal rheostat reverses the current going into the plating tank. This etching technique is often used to advantage in chromium plating to obtain good adherence of plated metals. The Universal unit is equipped with ammeter and voltmeter, although individual units may be specified without either or both.

The rheostat is available in four sizes. The smallest unit is rated at 30 or 60 amp., with plating line

voltages up to 12 volts. The largest is rated at 125 or 250 amp. over the same voltage range. All units are mounted in heavy steel cases that are open at top and bottom for ventilation.

The carbon-pile component is composed of rectangular carbon plates, formed into a single pile and housed in a one-piece steel box, the whole being more compact than conventional carbon-pile rheostats.

Proportioned for moderate temperature rise, the new rheostat operates at lower temperatures than multiple-tube or standard rheostats. Resistance changes range as high as 50 to 1.

Upright Self-contained Backstand

IN Fig. 3 is shown a new addition to the range of abrasive-band machines manufactured by the R.J.H. Tool and Equipment Co. Ltd., of Artillery Street, Heckmondwike. This machine is a double-ended self-contained upright model and is powered by a 4-h.p. totally enclosed motor. It incorporates "Major" backstand idler units and is designed to use standard 11 ft. 4 in. \times 4 in. abrasive belts.

The machine can be supplied with 1500 r.p.m. spindle speed motor, which using 14 in. dia. \times 4 in. face contact wheels, gives a band speed of 5500 ft. per min. suitable for heavy-duty grinding and fettling of rough castings. Alternatively a 3000 r.p.m. spindle speed, used with 10 in. \times 4 in. contact wheels, gives approx. 7500 ft. per min. band speed suitable for lighter duty grinding or polishing.

Free band strapping may also be effected above the contact wheel. The pedestal is cut away at the front to allow ample working clearance around the sides and below the contact wheels. Floor space

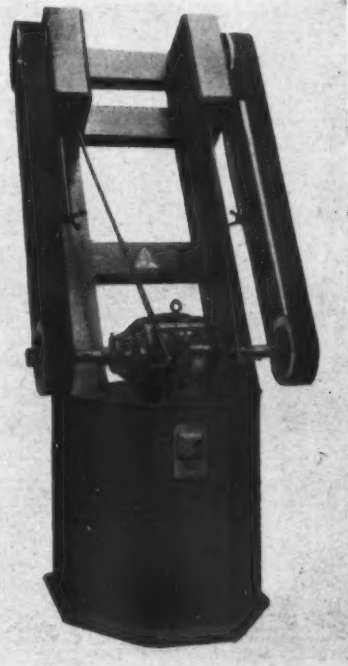


Fig. 3—
Upright
Self-
contained
backstand

required is only 2 ft. 6 in. \times 2 ft. 6 in. an important factor where room is limited. The overall height is 7 ft. 9 in. and both tension and tracking handles are arranged within easy reach of the operator, making possible quick belt changing.

The machine is strongly constructed of fabricated steel and has balanced pulleys mounted on sealed ball-bearing spindles to give rigid, vibration-free, working conditions. A push-button starter is incorporated in the front of the pedestal and the whole machine is ready for operation immediately after installation and wiring.

Bitumen Sealer

ALLWEATHER PAINTS LTD., 36, Great Queen Street, London, W.C.2 have recently introduced a new product designed for use where it is required to apply normal decorative finishes without involving the difficulty of effecting complete removal of bitumen-based paints present on surfaces treated with this type of material.

The sealer called Pitan Bitumen Sealer, acts as a barrier and prevents unsightly "bitumen bleed." It has a coverage of 60 to 70 sq. yd. per gal.

It is supplied only in white and the manufacturers state that the application of two coats is normally adequate.

Circulating Pump

FOR the handling of corrosive liquids increasing use is being made of modern plastics. An example

of this is Oxythene acid-circulating pump manufactured by Horwitch Smith and Co. Ltd., 42, Lower Loveday Street, Birmingham, 19. This pump is fabricated throughout from corrosion-resisting Oxythene V Grade (P.V.C.) material, in addition the pump has no stuffing box, instead, an Oxythene composition ring is used which is the subject of a patent application.

The pump will handle most strong acids and a range of other chemicals at working temperatures of up to 60°C. It is also useful for pumping food liquors etc., where freedom from contamination is essential. Two types are available, viz. the normal non-priming circulating type V.P.I.N. and the special pattern self-priming type V.P.I.S.

High-Power Industrial Ultrasonic Generator

THE Mullard Low-Frequency Ultrasonic Generator Type E7696 is a new general-purpose equipment with an output power of 2kW in the frequency range 10 to 30 kc per sec. It has been designed as a power source for magnetostrictive transducers used for ultrasonic cleaning, degreasing, soldering, tinning and drilling. Robust construction, conservative ratings, automatic protection circuits, and simple controls, make the generator suitable for everyday industrial use.

Full protection against overload and open circuit of the output is provided by special circuits. Further details may be obtained from Mullard Ltd., Century House, Shaftesbury Avenue, London, W.C.2.

Classified Advertisements

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